

NITROGEN AVAILABILITY FROM PLANT RESIDUES  
IN SELECTED OXISOLS AND ULTISOLS

BY

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To my son, my wife and  
the one we are all expecting.

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The extent of N mineralization from  $^{15}\text{N}$ -labelled plant residues with widely different C:N ratios, the N uptake from these residues by two upland rice crops, and the effect of previous fertility programs on the above parameters were studied using samples obtained from two long-term field experiments being conducted on two Brazilian Oxisols, i.e., an Acrustox and a Haplustox.

In a glasshouse experiment, residues of grain sorghum (Sorghum bicolor (L.) Moench) and white clover (Trifolium repens L.), grown with  $^{15}\text{N}$ -ammonium sulphate, were added to soils from the above experiments and two crops of upland rice (Oriza sativa L.) were grown. The whole rice plant was harvested each time, with unlabelled rice residue replacing the harvested plants after the first crop. Dry matter yield, total Kjeldahl N (TKN), N uptake, and  $^{15}\text{N}$  recovery

were evaluated for grain, root, and top portions of the plant. After two crops, the soils were evaluated for the  $^{15}\text{N}$ -plant residue remaining in the soil and unaccounted for N. Carbon dioxide evolution from the original soil samples was also measured in a laboratory incubation study.

The legume residue consistently released N in larger quantity and more rapidly than grass residue. Delayed grass residue decomposition resulted frequently in higher yields in the second crop. Results suggested that plant  $^{15}\text{N}$  uptake depended upon the N content of the residue, while N losses were related to soil and environmental conditions.

Carbon dioxide evolution from soil obtained from the cropped Acrustox treatments was lower than from the virgin soil. This was interpreted as a reduction in the more easily oxidizable portion of soil organic matter. This trend was more intensive for the low fertilization program. In the Haplustox soil, a trend was observed toward less  $\text{CO}_2$  evolution in those fertility programs where the crop residues had been removed. Clearing the native vegetation and plowing under the native grassland of the Haplustox soil produced  $\text{CO}_2$  evolution decrease as for a cropped fertility program with crop residue removed.

In the cropped treatments of both Oxisols, N recovery from plant residues by two rice crops averaged 25% with legume residue and 9% with grass residue. Results suggest that leguminous plant residues can be an alternative N source for rice grown on these soils.

## CHAPTER 1 INTRODUCTION

The largest available area in the world suitable for extension of modern agriculture without need of destroying forests seems to be the Brazilian cerrados (Dobersiner, 1977). Cerrado is defined as a semideciduous, xeromorphic vegetation dominant in central Brazil. It is concurrently a climatic, topographic and edaphic climax (Eiten, 1975). There are 185 million hectares under cerrado vegetation. This represents about 20% of the area of Brazil, occupying its central-west portion (Silva, 1977). The area under the cerrado socioeconomic pattern occupies 284,725,200 ha, representing 33.45% of the country (Gusmão, 1979). Use of N fertilizer in the cerrado region is limited due to lack of availability and high cost. Thus, management of crop residues and green manures becomes an important consideration for improving crop yields in this region. As pointed out by Baldock and Musgrave (1980), good estimates of the effects of mineral fertilizers, manures, legumes, and their combinations in various cropping systems and environments are important, not only for maintaining efficient crop production, but also for reducing energy use in agriculture. In contrast to locally produced phosphate and

like, N fertilizer has to be transported to the cerrados region. Recycling of crop residues and green manuring have been considered as alternatives to complement N fertilizer needs. Cultivation of legumes has been studied and recommended following commercial crops to recover residual fertilization and increase soil N content (Silva, 1977; Pereira and Kage, 1979; Brasil, 1982). Besides the N effects involved, plant residues can increase soil organic matter (OM) content which reduces P fixation in variable-charge soils. Also, adsorbed silica resulting from plant recycling could cause decreased P sorption capacity (Uenara and Gillman, 1981).

The objectives of this study were to 1) determine the extent of N mineralization from  $^{15}\text{N}$ -labelled plant residues with widely different C:N ratios, 2) measure N uptake from plant residues by two upland rice crops, and 3) evaluate the effect of soil types and field treatments on the above parameters.

## CHAPTER 2 LITERATURE REVIEW

### The Cerrado Region

Cerrado means dense, close or thick in Portuguese. Originally, this type of vegetation was referred to as "campo cerrado." Common usage dropped the noun, but the adjective remained to designate both the vegetation and the region. By definition, cerrado is a semideciduous, xeromorphic vegetation dominant in Central Brazil (Fig. 2.1). It is concurrently a climatic, topographic and edaphic climax. This definition encompasses shrubs and trees of varied height and density which create a continuum from "campo limpo" (clean grassland), to cerrado (dense grassland), to "cerradão" (tall cerrado) to semideciduous forest. Earlier theories attributing formation of the cerrado vegetation to anthropogenic factors such as fire have not been considered recently (Eiten, 1975). For further discussion of cerrados and other South American savannas, see reviews by Eiten (1975) and Beard (1953).

The predominant climate in the cerrado area is characterized by rainy summers and dry winters. In the Brasília region (Fig. 2.1), the average annual rainfall is



Figure 2.1 - Location of the cerrados region in Brazil (Brasil, 1978b).

around 1500 mm and is concentrated between October and May (Brasil, 1966; Brasil, 1978). In the cerrado region as a whole, the annual rainfall precipitation ranges from 750 mm in the northeast limit to over 2000 mm at the southern border (Eiten, 1972).

A very important aspect of the cerrado rainfall pattern is the occurrence of "veranicos" (short summers), which are dry spells within the rainy seasons. They vary in intensity and affect the potential crop production directly or by influencing insect and disease outbreaks. The frequency of the dry spells in the region of Brasília is shown in Table 2.1 (Silva, 1977).

Table 2.1 - Frequency of dry spells ("veranicos") in the rainy seasons in the Brasília region. (Silva, 1977)

| consecutive days<br>without rain | frequency   |
|----------------------------------|-------------|
| 8 or more                        | 3 / year    |
| 10 or more                       | 2 / year    |
| 13 or more                       | 1 / year    |
| 18 or more                       | 2 / 7 years |
| 22 or more                       | 1 / 7 years |

Most of the soils under cerrado vegetation are Oxisols, but considerable areas are Entisols, Inceptisols, and a few Ultisols are also present. The predominant Oxisols are

classified in the great groups Acrustox and Haplustox (Soil Taxonomy-USDA, 1975). In the Brazilian Soil Classification System, the Acrustox soil corresponds to Latossolo Amarelo (LA) (Yellow Latosol), and the Haplustox soil corresponds to Latossolo Escuro (LE) (Dark Latosol). The soil moisture regime is ustic and the soil temperature regime is isohyperthermic (Lopes and Cox, 1977).

The clay mineral fraction of these soils consists mainly of kaolinite, iron oxides, and gibbsite. High P fixation, a low level of available nutrients, low pH, high Al saturation, and low cation exchange capacity (CEC) are typical characteristics of these soils. Organic matter (OM) contents range from  $0.7 \text{ dag kg}^{-1}$  to  $6.0 \text{ dag kg}^{-1}$ , with a median of  $2.2 \text{ dag kg}^{-1}$  (Lopes and Cox, 1977). The effective CEC of these soils increases markedly with increasing levels of OM at pH values greater than 5.5. When the pH is less than 5.5, there is no relation between CEC and OM content. Liming is important in these soils to achieve a pH at which there would be appreciable dissociation of the carboxyl and phenol groups of OM and/or hydrolysis of bound trivalent metals (Lopes and Cox, 1977).

#### Decomposition of Soil Organic Matter of Tropical Soils

The amount of research on soil OM of tropical soils is small when compared with research done in soils of temperate

climates. However, studies conducted in analogous situations can be useful to support working assumptions.

Rodriguez and Perez (1977) studied the effect of rice cultivation on soil N availability in an Alfisol and in a Vertisol from Chile. Alternate flooding and drying of these soils caused an abrupt yield decrease as cropping cycles were repeated. A reduction in OM content was not observed in these soils. They fractionated the humus and determined that the degree of humification and polymerization of the humic substances changed which decreased availability of N. These authors reviewed several studies (Bremner, 1967; Mayaudon, 1968; Verma et al., 1975) which indicated that nitrogenated compounds, like C compounds, reach a high biological stability when bound to phenolic units of the humic substances. This stability increased with degree of organic matter polymerization. Therefore, nitrogenated organic compounds attached to phenolic units would be protected against microbial attack. Nguyen and Dommergues (1970) incubated two soils which were treated to simulate thermic and hydric conditions of a temperate and a tropical soil. A positive influence of the alternate wet and dry cycles on the neoformation of highly polymerized humic acids was found. These cycles increased the microbial oxidation of OM and at the same time increased polymerization which, in turn, increased the relative content of stable residual OM. Aomine (1972) studied N availability and humic matter

of Chilean Andosols. He compared northern soils, with markedly cyclic wet and dry seasons, and soils from the south, which had less differentiated wet and dry seasons. He found higher humification and polymerization associated with lower N mineralization in the northern soils. This suggested that soils with diverse moisture seasons contained N in forms that were biologically more stable thus slowing down N mineralization.

Broadbent and Nakashima (1965) stated that N which is not removed by plants, lost by drainage, or volatilization becomes combined in increasingly stable organic forms. Hauk (1973) described research results from  $^{15}\text{N}$  studies indicating that applied inorganic N goes through a series of mobilization-immobilization processes and gradually reverts to forms which mineralize at a slow but rather constant rate. Allen et al. (1973) studied the chemical distribution of residual fertilizer N and found that the N, once incorporated into soil OM, became increasingly stable with time and was not readily mineralized or subject to leaching. According to Hebert (1962), the highly-labile amino sugar portion of immobilized N can be readily mineralized and released in repeated cycles of mineralization and immobilization.

Stevenson (1982b) discussed the use of  $^{14}\text{C}$ -labelled substrates in soil OM studies and indicated that part of the residual C, after the most active phase of decomposition was

completed, occurs as microbial products and part as resistant plant remains. A decrease in OM decomposition rate with time is not believed to be entirely caused by differences in the rate at which the various plant components decompose. Decomposition rate also decreases because decomposable constituents (sugars, cellulose, etc.) are easily resynthesized into microbial components which are more resistant to decomposition than is the initial plant material.

Plant residues are often evaluated as soil amendments by their N content. Smith and Peterson (1982) generalized that crop residues containing  $1.5 \text{ dag kg}^{-1} \text{ N}$  or more would decompose at "normal" rates without net immobilization of soil N. Crop residues containing less than  $1.5 \text{ dag kg}^{-1} \text{ N}$  were considered deficient in N and would lead to depletion of available forms of soil N during residue decomposition.

The C:N ratio of plant residues may not be a reliable indicator of decomposition rate. For example, Kanamori and Yasuda (1979) found that softwood barks (C:N ratio 579) and peat moss (C:N ratio 76) showed similar decomposition rates after three months of incubation. Abd-el-Malek (1977) cited age of the plant, its lignin content and degree of disintegration along with environmental conditions as governing the decomposition rate. In addition, Dormaar and Pittman (1979) pointed out that the N organic residues may be structurally

different, with different degrees of resistance to microbial attack.

### Effect of Organic Matter on Nutrient Availability

Greenland (1972) observed that the influence of soil biological and organic components on plant nutrition is of great importance, particularly in relation to the continuing ability of soils to sustain vigorous plant production. According to Charreau (1975), organic matter also influences soil physical properties such as macrostructure, water storage, aggregation, and soil stability, and prevents soil hardening and compaction. With respect to soil chemical properties, the OM contributes to exchange capacity, which is very important in highly-weathered soils. Organic matter also plays an important role in the release of various nutrients (N,S,P) and readily forms complexes with heavy metals.

Plant residues can increase soil OM content, which reduces P-sorption capacity in variable charge soils. Also, silica originating from plant residues could be adsorbed onto soil surfaces and result in reduced P-sorption capacity (Uehara and Gillman, 1981). According to Charreau (1975) adsorption of OM to oxides results in decreased fixation of added P. Singh and Jones (1976) studied the influence of seven organic residues on sorption and desorption of P by a

high P-fixing soil (Typic Vitrandept). After incubation for 30 days, all residues decreased the amount of P sorbed by the soil, resulting in higher P levels in the equilibrium soil solution. However, after soil incubation for either 75 or 150 days, the P content of organic residues affected sorption of added P and desorption of sorbed P. The critical level of P in organic residues which resulted in no reduction of available soil P was  $0.3 \text{ dag kg}^{-1}$ . They suggested that P fertilizer rates estimated from sorption isotherms may need to be modified after addition of organic residues.

Sharma et al. (1960) attempted to define the limits of soil organic C for rating soils into low, medium and high categories with respect to soil P availability for potatoes grown on acidic sandy loam soils of India. These authors commented that organic C has been commonly employed for assessing the availability of soil N to plants but no attempt had been made to use it as an index of the availability of soil P, although its positive role is well understood. Potatoes were grown in 47 soils with 0 (control) and  $44 \text{ kg P ha}^{-1}$ . Simple correlation coefficients were calculated between tuber yield and values of soil organic C and soil P. Organic C and Bray-1 extractable P were highly correlated with yield from the control plots. Organic C was also highly correlated with Bray-P. These results showed that the high correlation of organic C with

yield could result from a positive association of organic C with Al-P and Fe-P. Soils containing organic C lower than  $1.3 \text{ dag kg}^{-1}$  and Bray-P lower than  $19.1 \text{ mg kg}^{-1}$  were in the low to medium range of fertility, needing P application. Soils containing organic C and Bray-P higher than the above test values were in the high fertility class, and P application might not be economical.

Venkateswarlu et al. (1978) studied the relationship between rice dry matter yields (DM), and P and N content of stubble. These authors concluded that recycled rice stubble may contribute from  $0.9$  to  $2.5 \text{ Mg DM ha}^{-1}$  containing  $5$  to  $24 \text{ kg N ha}^{-1}$  and  $0.75$  to  $3.3 \text{ kg P ha}^{-1}$ .

Bloom et al. (1979) found that addition of OM to an acid soil decreased the concentration of Al in the soil solution and decreased the effects of Al toxicity on plants, compared to the original soil adjusted to the same pH. They concluded that the effectiveness of OM in lowering the concentration of toxic trivalent Al depended on the soil pH and the base saturation of the soil. Since equilibrium concentrations of soluble Al from soil minerals are very low, yearly additions of OM may be effective in reducing Al toxicity. Mutatkar and Pritchett (1966) also considered the relationship between OM losses in tropical ferrallitic soils and toxic Al. They demonstrated that accumulation of OM in many tropical soils was associated with soils high in Al content. At soil pH values above 4.8, exchangeable Al was

negligible and the mineralization of organic matter increased.

Kang and Uehara (1974) conducted studies on Oxisols and Ultisols and found that addition of organic materials can lower the pH at zero point of charge, thereby increasing the cation exchange capacity, and also increasing the negative surface density of these soils.

Thomas (1975) found that the amount of Al extracted by 1 M KCl was decreased as the OM content was increased at any given pH level in samples from six depths of a Maury silt loam which varied in OM from 5.1 dag kg<sup>-1</sup> to 0.8 dag kg<sup>-1</sup>. With these results, he was able to explain the successful growth of crops in killed sods where the surface soil pH was less than 5 but high in organic matter.

The survey of Neptune et al. (1975) illustrated the dependence of S supply on soil OM. They found that 89% of the total S in a selected group of Brazilian soils was in organic form. Seven percent of the organic S was C-bonded.

#### Effect of Green Manures and Plant Residues on Soil Productivity

Cultivation of legumes has been studied and recommended after commercial crops to recover residual fertilization and increase soil N content (Silva, 1977; Pereira and Kage, 1977; Brasil, 1982).

Baldock and Musgrave (1980) analyzed the effects of crop sequences, mineral fertilizer, manure and legumes on crop yields and soil fertility in a long-term experiment (1955 to 1968) in New York State. The crop sequences included continuous corn, winter wheat, and grass and legume forage species as well as several five-phase rotations of corn, small grains, and forage crops. They stated that there are cases where the effects of legumes and manure are beyond the inorganic fertilizer value. They added that energy shortages, coupled with the high energy input required to produce and transport mineral fertilizer, have prompted some authorities to inquire if manure and legumes can replace some or all of the mineral fertilizers used in crop production. Two years of alfalfa apparently contributed  $136 \text{ kg N ha}^{-1}$  to subsequent crops. Manure apparently supplied 5-1-4 kg N-P-K  $\text{ha}^{-1}$  per metric ton. The effects of manure and crop rotation were limited to their plant nutrient contributions in corn under the conditions of the experiment. They found that rate of OM decomposition was higher in continuous corn than in sequences involving more than one species. They attributed this to less soil cover with corn during the summer months leading to higher soil temperatures or to more primary tillage and cultivation causing more aeration and thus greater OM decomposition. However, interseeding ryegrass was sufficient to maintain the OM level. They calculated that the amount of organic

material required to maintain a constant soil OM level was  $7.7 \text{ Mg DM ha}^{-1}$  for continuous corn and  $4.1 \text{ Mg DM ha}^{-1}$  for other systems involving alfalfa, birdsfoot trefoil, bromegrass, oats, ryegrass, timothy, and wheat.

In the above study, extractable P increased over the course of the experiment with all crop systems. The increase was a linear function of the net P additions. Even at zero net addition, the available P was found to increase slightly. From these results, the above authors concluded that on these soils the plant nutrient requirements of field crops could be completely supplied by legumes and manure, by mineral fertilizers alone or by some combination of the above without leading to decreases in soil fertility and productivity.

Both the direct and carryover effect of green manuring was studied for two years by Tiwary et al. (1980) on upland rice under rice-wheat rotation in a light textured alluvial soil. They observed that the mean plant concentration of N, P, and K at tillering stage was significantly higher with green manuring than that under fallow treatment. Rice yield and uptake of nutrients in grain and straw also increased considerably with green manuring. Rice grain yield with  $40 \text{ kg N ha}^{-1}$  plus green manuring was comparable to  $120 \text{ kg N ha}^{-1}$  after fallow. Increasing the supply of mineral N further increased the concentration of N, P, and K in the plants both at tillering stage and in uptake by grain and

straw. Removal of P from soil when fertilization consisted of green manuring and  $40 \text{ kg N ha}^{-1}$  was always higher than under  $120 \text{ kg N ha}^{-1}$  without green manuring. The favorable effect of green manuring on uptake and utilization of P by the crops was explained by the liberation of organic anions and hydroxy acids during the decomposition of OM. This mechanism could have led to complexation or chelation of Fe, Al, Mg, and Ca, thereby preventing these cations from reacting with phosphate ions to form insoluble phosphate. This would improve the availability of P in soil, and subsequently increase P uptake by the crop. The decomposing OM might also have solubilized native soil K (Kute and Mann, 1969; Debnath and Hajra, 1972). Green manuring also increased the available P of the soil by 107% for the first crop and 65% for the second crop, and available K by 175% and 51% during the two years of the experiment, respectively. Tivary et al. (1980) concluded that, in the rice-wheat rotation, green manuring would be beneficial to rice and the succeeding wheat crop.

Gaur and Mukherjee (1980) conducted field experiments to investigate the effect of organic mulching on soil nutrient status, microbiological properties, and yield of corn and green gram crops. The inorganic N content of the soil was increased due to stimulation of the microbial population and higher moisture content due to mulching (wheat straw). Available P was also increased by adding

mulch. This was attributed to increased activity of P solubilizing bacteria and fungi. Above all, the incorporation of organic mulch significantly increased wheat yield.

Thind et al. (1979) reported the effect of four years of leguminous and non-leguminous crop rotations on nutrient status and structure of a Typic Ustochrept. Nine rotations were tried, involving corn, wheat, cowpea, green gram, potato, peanuts, soybean, and periods of fallow culture. All rotations increased N and soil organic C. The C increase was less under maize-wheat-fallow rotation than under other crop rotations. The maximum C increase (0.12%) was under a peanuts-wheat-corn (fodder) rotation. This increase was attributed to the accumulation of more root residues in the soil after crop harvest. The maximum N accumulation occurred in rotations including peanuts. Leguminous crops like peanuts shed leaves, which also add to the organic matter of the soil.

## CHAPTER 3 MATERIALS AND METHODS

### Soils

#### Oxisols

Soil samples representing the Oxisol order were obtained from the Centro de Pesquisa Agropecuária dos Cerrados (CPAC; Cerrados Agricultural Research Center) in the Brazilian capital of Brasília, at 15°35'30" S and 47°42'30" W (Fig. 2.1). The area is gently sloping, with flattened hill tops and pediments hundreds to thousands of meters long. The slopes vary between 1 and 10%, with the most common being between 1 and 4%. Vegetation associated with the LA soil is cerrado; vegetation associated with the LE soil is a gradient from cerrado to cerrado vegetation. The CPAC area is geologically characterized by Tertiary-Quaternary sediments overlaying the highest portions of the landscape, and quartzites, fillites, and schists in the lower portions.

Soil samples were collected from ongoing long-term studies, one from the LA soil and one from the LE soil. Both areas were in their native status when cleared for the installation of the experiments. The experiment on the LA

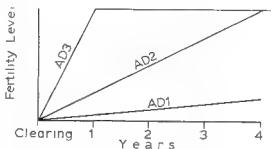
soil was designed to study three ways to upgrade soil fertility, depending on the resources of the farmer. The levels of fertilization were determined by prior research (Table 3.1 and Fig. 3.1). The experiment involves nine crop-sequence/ fertilization combinations in 0.5 ha (100 x 50 m) plots. Sampled plots are indicated in Fig. 3.1. The choice of the rice-soybean-corn-soybean-soybean sequence was based on grain yield criterion. At sampling date (June, 1982), the fifth crop had been harvested. Sixty soil subsamples were collected between rows of each plot. Each sample was collected to a depth of 20 cm. The virgin soil was similarly collected in an area under native cerrado vegetation contiguous to the experiment.

The LE samples were collected from a field experiment designed to evaluate the effect of soil management factors (liming and residue recycling) on soil organic matter status and grain yields. The experimental layout is shown in Figure 3.2 and the treatment schemes are shown in Table 3.2. Sampled plots (June, 1982) are indicated in Figure 3.2. The samples are composites of 60 subsamples (fifteen from each of the four replications), collected to a 20 cm depth. The cropping treatments selected for this study were based on grain yield performance at the end of the fifth crop season. At sampling time, green manures had not been incorporated into the soil.

Table 3.1 - Fertilization scheme in the LA (Acrustox) experiment treatments.

| Year                                           | Treatment | Fertilization |     |    |    | Application mode  |
|------------------------------------------------|-----------|---------------|-----|----|----|-------------------|
|                                                |           | N             | P   | K  | Zn |                   |
| ----- kg ha <sup>-1</sup> -----                |           |               |     |    |    |                   |
| First<br>(1977)<br>through<br>Fourth<br>(1980) | AD1       | 3             | 22  | 21 | -  | banded, annual    |
|                                                | AD2       | 9             | 65  | 62 | -  | banded, annual    |
|                                                | AD3       | -             | 175 | 83 | 10 | broadcast in 1977 |
|                                                |           | 3             | 22  | 21 | -  | banded, annual    |
| -----                                          |           |               |     |    |    |                   |
| Fifth<br>(1981)                                | all       | 3             | 22  | 21 | -  | banded            |

# Alternatives for soil fertility reclamation LA - Acrustox



## Field layout

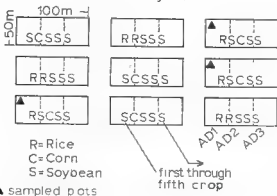


Figure 3.1 - LA (Acrustox) Central Experiment layout and soil fertility reclamation alternatives. See Table 3.1 for explanation of AD1, AD2, and AD3.

Table 3.2 - Management variables and fertilization scheme in the LE (Haplustox) experiment.

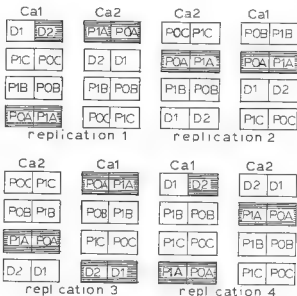
| Line                            | Residue management               | years         |      |               |      |      |      |
|---------------------------------|----------------------------------|---------------|------|---------------|------|------|------|
|                                 |                                  | 1976          | 1977 | 1978          | 1979 | 1980 | 1981 |
| none                            | native grassland<br>plowed under | --            | --   | --            | --   | --   | --   |
| Ca1<br>1<br>Mg ha <sup>-1</sup> | PO-residues<br>removed           | S             | S    | C             | C    | S    | S    |
|                                 | Pi-residues<br>incorporated      | S             | S    | C             | C    | S    | S    |
| Ca2<br>4<br>Mg ha <sup>-1</sup> | PO-residues<br>removed           | S             | S    | C             | C    | S    | S    |
|                                 | Pi-residues<br>incorporated      | S             | S    | C             | C    | S    | S    |
| Tillage                         |                                  | --Rotavator-- |      | --disc plow-- |      |      |      |

S = soybean, C = corn

Fertilization scheme. Rates in kg ha<sup>-1</sup>.

| Nutrient       | Source                    | First year<br>broadcast | All years<br>row |
|----------------|---------------------------|-------------------------|------------------|
| P              | Single super<br>phosphate | 131                     | 31               |
| K              | KCl                       | 83                      | 37               |
| Micronutrients | Fritted                   | 40                      | 40(only 1981)    |
| N              | Urea                      | 20(only rice)           | 20(rice,corn)    |

# LE -Haplustox - Organic Matter Experiment Field Layout



PO - crop residues removed

P1 - crop residues returned

Ca1- 1 t/ha lime

Ca2- 4 t/ha lime

D2 - native grassland plowed under, no lime

▨ sampled plots

A, B, C - crop sequences

Figure 3.2 - LE (Haplustox) experiment layout. Crop sequences are described in Table 3.2.

### Ultisols

Two Ultisols, Dothan and Troup, obtained in Jay, Santa Rosa County, State of Florida (Fig. 3.3), were included in the study for comparison purposes.

The Dothan and Troup series are classified as Plinthic Paleudult, fine loamy, siliceous, thermic, and Grossarenic Paleudult, loamy, siliceous, thermic, respectively. At the sampled site, the soils occur in a long catena with Troup occupying the upland and Dothan the pediment footslope. A swampy area constitutes the alluvial toeslope. The parent materials are described as marine deposits of unconsolidated sands and clays (University of Florida, 1979). The climate is warm and humid (University of Florida, 1979). The annual mean temperature is 18.3 C and the annual rainfall is 1702 mm (Bradley, 1980).

Dothan soil was sampled in a 10 m wide uncultivated strip between experimental areas. A 30 cm deep slice, 1.5 m wide, was collected. This comprised the A horizon. Troup soil was similarly sampled from an uncultivated strip, in a trench dug 1 m from a fence. Most of the abundant grass stolons were removed.

The sampled area had last been logged approximately 35 years ago, with the original vegetation consisting of pines and mixed hardwoods (University of Florida, 1974). The present use is mostly for row crops. The sampled strip was covered with weeds and grasses and had never been planted.

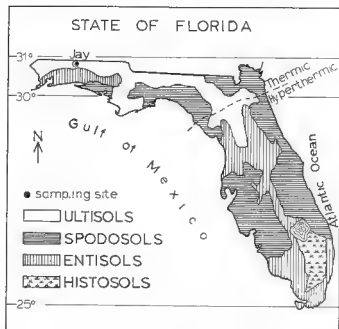


Figure 3.3 - Location of the Ultisols sampled in Florida (University of Florida, 1979).

### Glasshouse Experiment

The extent of N mineralization from  $^{15}\text{N}$ -labelled plant residues (grass and legume), the N uptake from these residues by upland rice, and the effect of soil types and fertility programs on the above parameters were evaluated in a glasshouse study. Fifteen-N labelled white clover (Trifolium repens L., unidentified cultivar) and grain sorghum (Sorghum bicolor L. Moench, cultivar Funk's G522 DR) were used to represent legume and grass residues, respectively. Residues were added to 1 kg of soil per pot (96 pots in all) and two crops of upland rice (Oryza sativa L., cultivar GO-0008) were grown (Figure 3.3). Uptake of  $^{15}\text{N}$  by the rice was used as an indicator of residue N availability.

The experiment used a split-split-plot design with three replications. The two residue types were considered as main plots, the two crops as subplots and soil field treatments as sub-subplots. The soils were analyzed after the successive rice crops as a split-plot design, with residues as the main plots and field treatments as the subplots. Statistical analyses were performed through the Statistical Analysis System package (SAS) at the Northeast Regional Data Center of the University of Florida.

Twenty tensiometers were installed in the series of pots; 10 with the sorghum residue and 10 with the clover residue. Water tension was inspected at least once a day

## Glasshouse Experiment

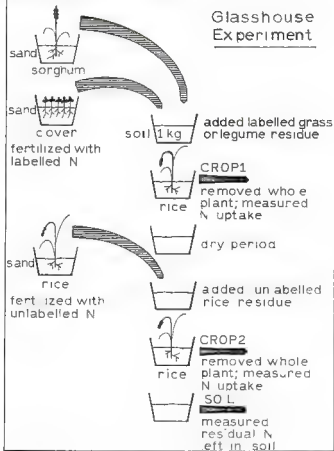


Figure 3.4 - Summary of glasshouse experiment procedures.

and adjusted to between 0.5 and 3 bar throughout the growing cycles. Occasional excesses of irrigation were collected in saucers and later returned to the soil.

Grain sorghum and white clover had been previously grown in sand pots, receiving  $180 \text{ kg } ^{15}\text{N ha}^{-1}$ , as ammonium sulphate ( $5.1 \text{ dag kg}^{-1} \text{ } ^{15}\text{N}$  in aqueous solution). The  $^{15}\text{N}$  was split between five irrigations to provide uniformly  $^{15}\text{N}$ -labelled plant material. At full maturity, the whole sorghum plant was harvested, oven-dried at  $65^\circ\text{C}$ , and ground to pass a 1 mm sieve. Clover growth was terminated by interrupting irrigation, concurrent with the end of the sorghum growth cycle. Roots and tops (including raquises) were combined and 10 g/pot were thoroughly mixed with the soil. This represented  $20 \text{ Mg ha}^{-1}$  of dry matter or 1 dag  $\text{kg}^{-1}$  residue added in weight basis. Samples of the residue mixture were saved for laboratory analysis. Carbon and N content and C:N ratio of the residues are shown in Table 3.3.

Three plants of upland rice were grown in the amended soil as well as in a parallel set of sand pots, where unlabelled ammonium sulphate was added. At planting, all pots received  $42.5 \text{ kg N ha}^{-1}$ ,  $44.4 \text{ kg P ha}^{-1}$  and  $83.0 \text{ kg K ha}^{-1}$ , from a finely ground commercial 4-8-8 fertilizer. Pots containing the various soil samples in addition received the organic residues. In the first crop, due to the poor growth and symptoms of N deficiency in the rice

Table 3.3 - Carbon content, N content and C:N ratio of the plant residues used in the glasshouse experiment.

| Residue                      | Crop to which added | C     | N     | C:N  |
|------------------------------|---------------------|-------|-------|------|
| --- dag kg <sup>-1</sup> --- |                     |       |       |      |
| Grain sorghum                | First               | 42.14 | 0.525 | 80:1 |
| White clover                 | First               | 40.25 | 2.219 | 18:1 |
| Upland rice                  | Second              | 36.47 | 0.726 | 50:1 |

plants with the grass residue treatments, 75 kg N ha<sup>-1</sup> were applied, in irrigation water in five installments to all treatments. For all calculations, a 20 cm hectare furrow-slice and soil bulk density equal to 1 were assumed.

At full maturity, the whole plants (grain, top and root) were harvested. Roots were separated from soil by dry sieving, breaking crumbs manually and blowing away the remaining small plant particles. Roots, tops and grain were oven-dried at 65 C, ground to less than 20 mesh and stored. Plants from the sand pots were processed as described for the previous sand-pot set, with roots and tops combined and 3.75 g/pot mixed with the same soil used to grow the first rice crop. This represented a total of 7.5 Mg ha<sup>-1</sup> of dry matter or 0.375 dag kg<sup>-1</sup> residue added on a weight basis. Except for the portion saved for laboratory analysis, all material harvested from the sand pots was

added to the soil prior to seeding the second rice crop. The interval (dry period) from the last irrigation of the first crop to the first irrigation and planting of the second crop was 140 days. The plant-free soil at the end of the second crop was dried in the glasshouse and ground in a ceramic mortar to pass a 1 mm sieve.

### Analytical Methods

Total N in soil and plant tissue was determined by a semi-micro Kjeldahl method as described by Bremner and Mulvaney (1982). The distillate was titrated and acidified with 2 ml of 1/12 N  $\text{H}_2\text{SO}_4$  and evaporated to about 2 ml on a hot plate. Nitrogen isotope ratio was determined by mass spectrometry. Calculations for  $^{15}\text{N}$  recovery were performed as proposed by Hauck and Bremner (1976).

Organic C was determined by Walkley-Black wet combustion (Allison, 1965). For C:N calculations, the C values determined by the Walkley-Black method were used without correction for oxidation efficiency, in order to direct the data analyses toward the more easily oxidizable portion of the organic matter. Carbon dioxide evolution was measured in a continuous  $\text{CO}_2$ -free air-flow system, with NaOH trap (Stotsky, 1965). Room temperature was kept between 22 and 26 C.

## CHAPTER 4 RESULTS AND DISCUSSION

Original soil samples were characterized for pH, C and selected nutrients. Since replicate samples were not available, no statistical analyses were conducted on these data. Statistical analysis was conducted for the LA and LE experiments separately, in addition, the four virgin soils (LA, LE, Dothan, and Troup) were statistically analyzed as a group.

Statistical analysis was conducted on CO<sub>2</sub> evolution, dry matter yield, total Kjeldahl N (TKN), and <sup>15</sup>N recovery from added residues. The atom % <sup>15</sup>N data were compared between plant parts. At the end of the glasshouse experiment, the <sup>15</sup>N remaining in soil, <sup>15</sup>N recovered by plants, the <sup>15</sup>N unaccounted for by the laboratory analyses, and the initial and final soil TKN and C:N ratio were statistically analyzed. One degree of freedom contrasts were used for specific comparisons of treatment effects. Throughout the presentation and discussion of the data, statistical differences were considered at the 5% significance level, unless otherwise specified. Computer outputs for the statistical analyses were edited and are shown in Appendices 1 through 3.

Acrustox (LA)Original Soil Sample Characterization

The field experiment from which soil samples were obtained was initiated in the 1977-1978 cropping season. Soil samples were taken at the end of the fifth year of the study. Double-acid extractable levels of selected elements are shown in Table 4.1. Nutrient levels were increased by all fertilization treatments compared to the virgin soil. Aluminum levels were not greatly affected by the treatments. Nutrient levels of the lower fertility treatment were generally lower than for treatments AD2 and AD3. This was reflected in crop yields for the first three years of the field experiment (Table 4.2). Yields for the final two years of the experiment are not available at this time. Increased yields resulted in more crop residue being returned to the soil. The highest fertilization levels (AD2 and AD3) resulted in the highest soil organic C and TKN levels, with considerable increases as compared to the virgin soil (Table 4.1). The increases in C content were 62% for the AD2 treatment and 49% for the AD3 treatment. The increases in TKN level were 63% for the AD2 treatment and 50% for the AD3 treatment. The lower fertilization level of the AD1 treatment did not increase the organic C level but did increase the TKN level by 25%. The resulting C:N ratios for the high fertilization treatments were not

Table 4.1 - Selected characteristics of LA samples used in the glasshouse experiment.

| Fertility program |     |                      |      |      | Double-acid extractable†        |     |    |    |     |     |
|-------------------|-----|----------------------|------|------|---------------------------------|-----|----|----|-----|-----|
|                   | pH  | C <sup>+</sup>       | TKM  | C:N  | Al                              | Ca  | Mg | K  | Zn  | P   |
|                   |     | dag kg <sup>-1</sup> |      |      | ----- mg kg <sup>-1</sup> ----- |     |    |    |     |     |
| AD1               | 5.5 | 1.03                 | 0.10 | 10.3 | 308                             | 208 | 56 | 16 | 1.4 | 2.0 |
| AD2               | 5.5 | 1.60                 | 0.13 | 12.3 | 364                             | 244 | 64 | 24 | 1.9 | 2.4 |
| AD3               | 5.5 | 1.48                 | 0.12 | 12.3 | 352                             | 324 | 64 | 16 | 2.2 | 3.2 |
| Virgin            | 5.3 | 0.99                 | 0.06 | 12.4 | 296                             | 20  | 4  | 16 | 0.3 | 1.2 |

<sup>+</sup> Walkley-Black method without correction for efficiency.

<sup>‡</sup> Mehlich I extractant.

Table 4.2 - Crop yields from the first three years of the LA soil study for the rice-soybean-corn-soybean-soybean sequence. (Brasil, 1980)

| Crop    | Year              | Soil fertility level            |      |      |
|---------|-------------------|---------------------------------|------|------|
|         |                   | AD1                             | AD2  | AD3  |
|         |                   | ----- Mg ha <sup>-1</sup> ----- |      |      |
| rice    | 1978 <sup>+</sup> | 0.18                            | 0.40 | 0.15 |
| soybean | 1979              | 0.70                            | 1.19 | 1.77 |
| corn    | 1980              | 2.38                            | 5.04 | 5.32 |

<sup>+</sup> Yields affected by a 42 day drought during the growing season.

different from the virgin soil; however the C:N ratio decreased considerably for the AD1 treatment. Carbon dioxide evolution from the original four soil samples over a 65 day period is shown in Fig. 4.1.

Carbon dioxide evolution for a 100 day period was calculated from the regression equations (Appendix 3) to represent the growth cycle of a short cycle upland rice cultivar, often called regionally "100 day rice." Carbon dioxide evolution up to 30 days was chosen arbitrarily as a threshold of the most active phase of organic matter mineralization. The data are shown in Table 4.3.

Cumulative  $\text{CO}_2$  evolved at 30 and 100 days was significantly different ( $<0.01$ ) among the four treatments. The contrasts tested showed differences between the virgin

Table 4.3 - Accumulated  $\text{CO}_2$  evolved from the original soils at 30 and 100 days, as calculated from the regression equations.

| Fertility<br>program | 30 days                                    | 100 days |
|----------------------|--------------------------------------------|----------|
|                      | ----- mg CO <sub>2</sub> /100 g soil ----- |          |
| AD1                  | 35.6                                       | 44.0     |
| AD2                  | 41.1                                       | 52.3     |
| AD3                  | 40.3                                       | 51.9     |
| Virgin               | 50.1                                       | 63.9     |

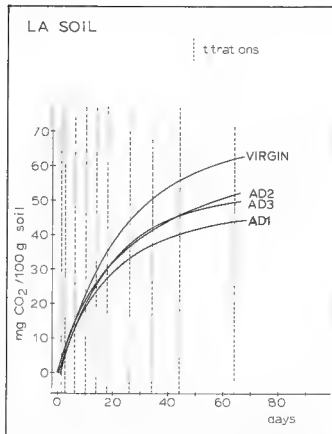


Figure 4.1 - Accumulated CO<sub>2</sub> evolution curves from the original LA soils experiment.

soil and the fertilized treatments at the 10% probability level. None of the contrasts between the fertilized treatments was significantly different (Appendix 3). Nevertheless, there was a clear trend in  $\text{CO}_2$  evolution which decreased from the virgin soil to the low fertilization level (Table 4.3). Cultivation apparently caused depletion of the more easily-oxidizable portion of the organic matter even though organic C levels were increased. This depletion was greater with the low fertilization level (AD1), likely because lower yields left less plant residues in the soil. Stevenson (1982a) reported that numerous investigations have shown losses of soil organic matter through cropping. When increases have occurred, they have been attributed to additions of plant and animal residues, or to introduction of leguminous crops on soil initially low in organic matter.

Correlations of  $\text{CO}_2$  evolved with soil TKN and C:N ratio were found at both 50 and 100 days. The virgin soil had the highest C:N ratio, lowest TKN level and the highest  $\text{CO}_2$  evolution (Table 4.1 and Table 4.3). A higher C:N ratio and C content, coupled with high metabolic activity, might indicate a larger proportion of low molecular weight C compounds in the free organic matter of the virgin soil. The increase in TKN with cultivation, even with the low-input fertility program, is unusual by most standards. However, it is understandable in face of the low TKN level in the virgin soil. The lowest TKN level and the highest

CO<sub>2</sub> evolved were observed in the virgin soil. An increase in TKN and decrease in CO<sub>2</sub> evolution in the cropped treatments suggest that cultivation decreased N availability. Attachment of N to phenolic units of organic matter has been suggested as a mechanism by which N becomes increasingly more protected from microbial attack (Rodriguez and Perez, 1977). Low fertilization (AD1) resulted in a more rapid depletion of the most active part of the organic matter as compared with the high fertilization level of the AD2 and AD3 treatments.

#### Nitrogen Uptake from Plant Residues by Upland Rice

Rice dry matter yield, N content (TKN), N uptake, and <sup>15</sup>N recovery, by plant component, are shown in Tables 4.4 and 4.5. Yields (average of two crops) were higher with clover residue than with sorghum residue. Rice plants receiving sorghum residues showed strong N deficiency symptoms in the beginning of the first crop, likely due to N immobilization caused by the high C:N ratio (80:1) of the sorghum residue. A difference in N mineralization between the two residues was reflected in different yield patterns between the first and second crops. With the sorghum residue, the highest yield was obtained with the second crop while the opposite occurred with the clover residue. In the second crop, sorghum residue apparently was able to provide mineralizable N while most of the mineralizable N from the clover residue had been utilized by the first rice crop.

Table 4.4 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake and  $^{15}\text{N}$  recovery from sorghum residues added to the LA soil.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Crop 1            |            |            |                      |                       |                          |
| AD1†              | Grain      | 633        | 2.0                  | 12.5                  | 1.8                      |
|                   | Top        | 2643       | 1.3                  | 35.2                  | 5.1                      |
|                   | Root       | 823        | 1.4                  | 11.2                  | 1.8                      |
|                   | Total      | 4099       |                      | 58.9                  | 8.7                      |
| AD2               | Grain      | 783        | 1.9                  | 14.5                  | 1.9                      |
|                   | Top        | 3807       | 1.3                  | 48.7                  | 6.1                      |
|                   | Root       | 1427       | 1.2                  | 17.1                  | 2.3                      |
|                   | Total      | 6017       |                      | 80.3                  | 10.3                     |
| AD3               | Grain      | 787        | 1.8                  | 14.2                  | 2.0                      |
|                   | Top        | 3373       | 1.1                  | 37.1                  | 5.3                      |
|                   | Root       | 1160       | 1.1                  | 12.8                  | 1.9                      |
|                   | Total      | 5320       |                      | 64.1                  | 9.2                      |
| Virgin            | Grain      | 387        | 1.8                  | 7.0                   | 0.9                      |
|                   | Top        | 1830       | 1.3                  | 23.4                  | 3.7                      |
|                   | Root       | 1413       | 0.9                  | 12.6                  | 2.1                      |
|                   | Total      | 3630       |                      | 43.0                  | 6.7                      |
| Crop 2            |            |            |                      |                       |                          |
| AD1               | Grain      | 2133       | 1.3                  | 26.9                  | 3.7                      |
|                   | Top        | 2647       | 0.4                  | 10.0                  | 1.3                      |
|                   | Root       | 1187       | 0.7                  | 8.7                   | 1.1                      |
|                   | Total      | 5967       |                      | 45.6                  | 6.1                      |
| AD2               | Grain      | 2293       | 1.3                  | 29.4                  | 3.7                      |
|                   | Top        | 2960       | 0.3                  | 10.1                  | 1.2                      |
|                   | Root       | 1240       | 0.7                  | 8.8                   | 1.0                      |
|                   | Total      | 6493       |                      | 48.3                  | 5.9                      |
| AD3               | Grain      | 2307       | 1.2                  | 28.4                  | 3.7                      |
|                   | Top        | 2583       | 0.4                  | 10.0                  | 1.1                      |
|                   | Root       | 1010       | 0.7                  | 7.5                   | 1.0                      |
|                   | Total      | 6170       |                      | 45.9                  | 5.8                      |

Table 4.4 - continued.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Virgin            | Grain      | 2083       | 1.2                  | 25.8                  | 3.3                      |
|                   | Top        | 2803       | 0.4                  | 10.1                  | 1.3                      |
|                   | Root       | 1863       | 0.7                  | 13.8                  | 1.8                      |
|                   | Total      | 6749       |                      | 49.7                  | 6.4                      |

<sup>+</sup> 52.52 mg N added as sorghum residue (3.729 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

<sup>‡</sup> AD<sup>1</sup>, AD<sup>2</sup> and AD<sup>3</sup> represent programs to increase fertility of the LA soil (see Table 3.1).

Table 4.5 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake and  $^{15}\text{N}$  recovery from clover residues added to the LA soil.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Crop 1            |            |            |                      |                       |                          |
| AD1†              | Grain      | 2313       | 1.8                  | 40.5                  | 6.4                      |
|                   | Top        | 5690       | 1.3                  | 75.1                  | 12.3                     |
|                   | Root       | 2033       | 1.3                  | 25.8                  | 3.9                      |
|                   | Total      | 10036      |                      | 141.4                 | 22.6                     |
| AD2               | Grain      | 2430       | 1.8                  | 43.0                  | 7.3                      |
|                   | Top        | 6100       | 1.5                  | 92.0                  | 15.5                     |
|                   | Root       | 1553       | 1.5                  | 22.8                  | 3.7                      |
|                   | Total      | 10083      |                      | 157.8                 | 26.5                     |
| AD3               | Grain      | 2370       | 1.9                  | 44.1                  | 7.8                      |
|                   | Top        | 5187       | 1.5                  | 75.7                  | 13.4                     |
|                   | Root       | 1483       | 1.4                  | 20.6                  | 3.4                      |
|                   | Total      | 9040       |                      | 140.4                 | 24.6                     |
| Virgin            | Grain      | 1547       | 1.6                  | 25.2                  | 4.4                      |
|                   | Top        | 3573       | 1.5                  | 51.8                  | 7.9                      |
|                   | Root       | 2510       | 1.1                  | 26.9                  | 4.2                      |
|                   | Total      | 7630       |                      | 103.9                 | 16.5                     |
| Crop 2            |            |            |                      |                       |                          |
| AD1               | Grain      | 1617       | 1.2                  | 19.4                  | 2.0                      |
|                   | Top        | 1923       | 0.4                  | 7.5                   | 0.8                      |
|                   | Root       | 643        | 0.9                  | 5.5                   | 0.6                      |
|                   | Total      | 4183       |                      | 32.4                  | 3.4                      |
| AD2               | Grain      | 1977       | 1.4                  | 27.5                  | 2.8                      |
|                   | Top        | 2873       | 0.5                  | 12.9                  | 1.3                      |
|                   | Root       | 1113       | 0.9                  | 9.6                   | 1.0                      |
|                   | Total      | 5963       |                      | 50.0                  | 5.1                      |
| AD3               | Grain      | 2253       | 1.4                  | 36.0                  | 3.2                      |
|                   | Top        | 2450       | 0.4                  | 10.3                  | 1.0                      |
|                   | Root       | 813        | 0.8                  | 6.3                   | 0.7                      |
|                   | Total      | 5516       |                      | 52.6                  | 4.9                      |

Table 4.5 - continued.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>*</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Virgin            | Grain      | 1653       | 1.4                  | 27.9                  | 2.4                      |
|                   | Top        | 2690       | 0.4                  | 11.3                  | 1.2                      |
|                   | Root       | 1540       | 0.8                  | 10.2                  | 1.1                      |
|                   | Total      | 5683       |                      | 49.4                  | 4.7                      |

\* 221.92 mg N added as sorghum residue (2.187 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

† AD1, AD2 and AD3 represent programs to increase fertility of the LA soil (see Table 3.1).

This pattern developed even with the addition of mineral N to all treatments during the first crop. Smith and Peterson (1982) indicated that crop residues containing  $1.5 \text{ dag kg}^{-1}$  N or more would decompose at "normal rates" without net immobilization of soil N. Residues containing less than  $1.5 \text{ dag kg}^{-1}$  N were considered deficient in N and would lead to depletion of available forms of soil N during the early stages of residue decomposition. Differences in rice yield due to residue type can thus be explained by the N contents of the residues, i.e.,  $0.53 \text{ dag kg}^{-1}$  for the sorghum residue and  $2.22 \text{ dag kg}^{-1}$  for the clover residue.

The difference in N mineralization rate between residues affected grain yield and N uptake by the grain more than it did biomass (root + top) yield. Grain yield was over three times greater with clover residue than with sorghum residue in the first crop. However, biomass yields were increased by less than two times. Apparently not enough N was available in rice plants grown with sorghum residue (prior to flowering) to allow optimum N transfer to the grain and thus grain yield was reduced more than biomass yield. Ladd et al. (1983) reported similar findings with rice. Salisbury and Ross (1978) described similar patterns of N transference in wheat and oat plants.

The results showed that the clover residue had the potential to provide mineral N for the crop shortly after its addition to the soil. Sorghum residue with lower N

content would need a longer N turnover period. This would require longer fallow periods and/or larger N mineral fertilization for the subsequent crop.

There was no effect of residue type on tissue TKN levels. The average TKN for the three plant parts combined was  $1.1 \text{ dag kg}^{-1}$  with sorghum residue and  $1.2 \text{ dag kg}^{-1}$  with clover residue. The amount of N taken up by plants, and yields, were higher with clover residue. These N recovery and yield differences reflect the higher amount of N available from the clover residue.

There were highly significant differences in TKN between the two rice crops for all plant components and both residues. In the first crop, the average tissue TKN was  $1.4 \text{ dag kg}^{-1}$  with sorghum residue and  $1.5 \text{ dag kg}^{-1}$  with clover residue; in the second crop, the average tissue TKN was  $0.8 \text{ dag kg}^{-1}$  and  $0.9 \text{ dag kg}^{-1}$  with sorghum and clover residue, respectively. Correlations of  $-0.80$  ( $0.01$ ),  $-0.95$  ( $0.01$ ), and  $-0.89$  ( $0.01$ ) were found between crop and root TKN, top TKN, and grain TKN, respectively. This indicated that the N content of rice plants consistently decreased from the first ( $1.4 \text{ dag kg}^{-1}$ ) to the second ( $0.8 \text{ dag kg}^{-1}$  N, crop. The addition of mineral N in the first crop ( $75 \text{ kg ha}^{-1}$ ) could have inflated this difference. However, with sorghum residue, yields were lower for the first crop than the second crop, despite the mineral N addition. Therefore, the additional mineral N alone would not be sufficient to have

caused the higher TKN levels in the first crop with both residues.

Nitrogen recovery in the whole plant by both crops averaged 14.8 and 27.1 dag kg<sup>-1</sup> from sorghum and from clover residue, respectively. The N recovered in the root + top, the portion generally returned to the soil, was 9.5 and 18.0 dag kg<sup>-1</sup>, from sorghum and from clover residue, respectively. Nitrogen recovery (% of added residue N) in the whole plant was approximately 92% higher from clover residue than from sorghum residue. For the returnable portion, this difference was 94%. The differences found in N recovery did not parallel the N added by the plant residues since the clover residue had 211% more N than did the sorghum residue. The wide difference in residue decomposition rate, as estimated by plant uptake, was in agreement with the threshold of 1.5 dag kg<sup>-1</sup> N content in plant residues for "normal" decomposition rates cited by Smith and Peterson (1982). This indicates that, above this limit, proportional gains in decomposition efficiency should not be expected.

Nitrogen recovery (root + top + grain) in two crops with clover residue ranged from 21.2 to 31.6 dag kg<sup>-1</sup>. This range was similar to that found by Ladd et al. (1983) for wheat in field microplots using Medicago littoralis residue, even though the C:N ratio was smaller (11:1) than in the clover residue used in the present study. With sorghum

residue, the N recovery in the whole plant was in the range of 13.2 to 16.1 dag kg<sup>-1</sup>.

Fertilization levels used in the field studies were also shown to affect N recovery from the residues. In the first crop, N recovery from sorghum residue added to the virgin soil was significantly lower (6.7 dag kg<sup>-1</sup>) than with the high fertilization treatments (AD2 and AD3), i.e., 10.3 dag kg<sup>-1</sup> and 9.2 dag kg<sup>-1</sup>, respectively. No significant differences were obtained in N recovery between treatments in the second crop. Nitrogen recovery from the virgin soil amended with clover residue (16.6 dag kg<sup>-1</sup>) was also significantly lower than that with the high fertilization treatments (AD2 and AD3) (26.5 dag kg<sup>-1</sup> and 24.6 dag kg<sup>-1</sup>). In addition, in the second crop the low fertilization treatment (AD1) resulted in lower N recovery (3.4 dag kg<sup>-1</sup>) than the two high fertilization treatments (5.9 dag kg<sup>-1</sup> and 5.7 dag kg<sup>-1</sup>), indicating that the low levels of fertilization used in the AD1 system resulted in the less favorable conditions for N recycling from the rapidly decomposing clover residue for the second crop. The lower fertility level for AD1 (Table 4.1) could have led to nutrient deficiencies earlier than in the AD2 and AD3 treatments. Similar fertility limitation would have prevented larger residue decomposition in the virgin soil during the first crop, thus providing a longer and steadier period of decomposition. The virgin soil had lower C (0.99

dag  $\text{kg}^{-1}$ ), TKN (0.08 dag  $\text{kg}^{-1}$ ), Zn (0.3 mg  $\text{kg}^{-1}$ ), and Ca + Mg (24 mg  $\text{kg}^{-1}$ ) as compared with the fertilized treatments, which averaged 1.37 dag C  $\text{kg}^{-1}$ , 0.12 dag TKN  $\text{kg}^{-1}$ , 1.81 mg Zn  $\text{kg}^{-1}$ , and 320 mg Ca + Mg  $\text{kg}^{-1}$ . These values indicated that a nutrient deficiency would be more likely to occur sooner with the virgin soil. In the first crop with both residues, N uptake and  $^{15}\text{N}$  recovery for the whole plant (Tables 4.4 and 4.5) followed the same trend as the C, N, and K values of the original soil samples (Table 4.2). This relationship was interpreted as a result of the higher K fertilization in the AD2 treatment (Table 3.1), which would have positively affected the accumulation of C and N. Results also suggest that the magnitude of N recovery from residues in the second crop are more likely to be dependent on residue type than on soil fertilization program.

In the statistical analysis of  $^{15}\text{N}$  recovery by the root + top plant components, i.e., the material which would be returned to the soil after grain harvest, no differences between fertilization programs were found for sorghum residue. Therefore, the soil fertility programs did not affect the amount of N recovered from sorghum residues which was made available to the second rice crop. For clover residue, differences were found between virgin soil (16.6 dag  $\text{kg}^{-1}$ ) and the two high fertilization treatments (18.1 dag  $\text{kg}^{-1}$ ) in the first crop, i.e., the recycled N which was made available to the second rice crop. For a third rice

crop, it is reasonable to expect that all fertilization treatments, with any of the residues, would show no difference in N recovered from the initial residues.

Nitrogen Remaining in Soil and Unaccounted for  
After Growth of Two Upland Rice Crops

Highly significant correlations were found between residue type and either the N from added residues remaining in the soil (negative) or taken up by plants (positive). A larger proportion of N from sorghum residue remained in the soil and a smaller proportion was taken up by plants as compared with the clover residue (Table 4.6). The N remaining in the soil averaged 66% of the amount added as sorghum residue and 50% as clover residue. Nitrogen remaining in soil and N taken up by plants were significantly different between residues.

The unaccounted for N (losses) averaged 19% and 25% of the N added to the soil as sorghum and clover residue, respectively. This difference was not significant. These results indicated that processes contributing to N losses from plant residues affected the two plant residues similarly. For the statistical analysis of the unaccounted for N, the log (Y+1) transformation was used to stabilize the variance (Steel and Torrie, 1980).

A highly significant negative correlation was found between TKN in the original soil samples and the unaccounted for N from sorghum residue at the end of the glasshouse experiment. A positive correlation was found between TKN in

Table 4.6 - Nitrogen remaining in soil, N recovered in two rice crops, N unaccounted for, and soil TNH and C:N ratio to the original, LA soil samples and at the end of the glasshouse experiment

| Fertility Residue<br>program |         | N                    |                            |                    | TNH                                     |                                    | C:N ratio                               |                                    |
|------------------------------|---------|----------------------|----------------------------|--------------------|-----------------------------------------|------------------------------------|-----------------------------------------|------------------------------------|
|                              |         | Remaining<br>in soil | Recovered<br>in 2<br>crops | Unaccounted<br>for | Original<br>soil<br>sample <sup>a</sup> | End of<br>glasshouse<br>experiment | Original<br>soil<br>sample <sup>a</sup> | End of<br>glasshouse<br>experiment |
|                              |         | g kg <sup>-1</sup>   |                            |                    | deg. kg <sup>-1</sup>                   |                                    |                                         |                                    |
| AD1                          | Sorghum | 69.2                 | 14.8                       | 16.0               | 0.10                                    | 0.11                               | 11.8                                    | 10.3                               |
|                              | Clover  | 55.1                 | 26.0                       | 21.0               |                                         | 0.11                               |                                         | 11.3                               |
| AD2                          | Sorghum | 67.4                 | 16.1                       | 16.5               | 0.11                                    | 0.12                               | 12.7                                    | 12.1                               |
|                              | Clover  | 52.3                 | 31.6                       | 16.5               |                                         | 0.13                               |                                         | 11.3                               |
| AD3                          | Sorghum | 72.6                 | 15.0                       | 12.4               | 0.12                                    | 0.13                               | 12.1                                    | 2.1                                |
|                              | Clover  | 44.9                 | 29.5                       | 25.6               |                                         | 0.11                               |                                         | 15.9                               |
| virgin                       | Sorghum | 54.0                 | 13.2                       | 12.8               | 0.08                                    | 0.07                               | 13.7                                    | 12.4                               |
|                              | Clover  | 49.0                 | 21.3                       | 29.5               |                                         | 0.08                               |                                         | 11.7                               |

<sup>a</sup> Same data as Table 4.1

the original soil samples with N remaining in soil. This showed that a low TKN level in the original soil sample corresponded to a high N loss and consequently less N from the added residue remained in the soil. No significant correlations were found with clover residue.

Levels of TKN in the soils at the end of the experiment were not statistically different from those of the original soils (Table 4.6). Changes in soil C:N ratios (from the initial samples to the end of the glasshouse experiment) were not significant for either residue.

Among the one degree of freedom contrasts for N remaining in soil and unaccounted for N, significant differences were only found between the virgin soil and the high fertilization treatments (AD2, AD3) with sorghum residue. In these treatments, the N remaining in the soil was 54% for the virgin soil and 49% for the high fertilization treatments. The unaccounted for N was 33% for the virgin soil and 16% for the high fertilization treatments.

The initial TKN values were significantly different between the virgin soil and low fertilization treatment (AD1) or the two high fertilization treatments (AD2 and AD3). At the end of the experiment, only the virgin soil and the high fertilization treatments differed in TKN. Since this situation was consistent with both residues, it can be concluded that addition of plant residues resulted in similar TKN levels in the fertilized treatments after two

crops. In a similar fashion, the C:N ratio was significantly different between the AD1 and the average of AD2 and AD3 treatments in the original soils, but was not significantly different at the end of the experiment.

### Haplustox (LE)

#### Original Soil Sample Characterization

The effect of liming level was still present after five annual crops (Table 4.7). The sum of Ca and Mg increased 163% from liming level 1 (Ca1, 1 Mg ha<sup>-1</sup>) to liming level 2

Table 4.7 - Selected characteristics of LE soil samples used in the glasshouse experiment.

| Fertility<br>program <sup>†</sup> | Double acid extractable* |                      |      |      |     |                     |    |    |     |     |
|-----------------------------------|--------------------------|----------------------|------|------|-----|---------------------|----|----|-----|-----|
|                                   | pH                       | C <sup>‡</sup>       | TKN  | C:N  | Al  | Ca                  | Mg | K  | Zn  | P   |
|                                   |                          | dag kg <sup>-1</sup> |      |      |     | mg kg <sup>-1</sup> |    |    |     |     |
| Ca1POA                            | 5.1                      | 1.24                 | 0.12 | 10.3 | 580 | 132                 | 16 | 28 | 1.1 | 8.0 |
| Ca1P1A                            | 4.9                      | 1.26                 | 0.13 | 9.7  | 540 | 164                 | 24 | 44 | 1.3 | 6.4 |
| Ca2POA                            | 5.5                      | 1.21                 | 0.11 | 11.0 | 468 | 368                 | 76 | 20 | 1.2 | 7.2 |
| Ca2P1A                            | 5.4                      | 1.30                 | 0.12 | 10.8 | 480 | 360                 | 80 | 40 | 1.2 | 6.4 |
| Virgin                            | 5.0                      | 1.22                 | 0.13 | 9.4  | 588 | 28                  | 12 | 24 | 0.2 | 2.4 |
| NCPU                              | 4.8                      | 1.13                 | 0.11 | 10.3 | 600 | 20                  | 4  | 8  | 1.1 | 2.4 |

<sup>†</sup> See Table 3.2.

<sup>‡</sup> Walkley-Black method without correction for efficiency.

\* Mehlich I extractant.

(Ca2, 4 Mg ha<sup>-1</sup>). At liming level 1 (Ca1), the return of crop residues to the soil resulted in an increase of 27% in the Ca + Mg level. At liming level 2 (Ca2), there was no difference in Ca + Mg with and without added crop residues. This could be attributed to the higher liming level overwhelming the crop residue effect. The ratio of Ca + Mg + K to Al was 0.3, 0.4, 1.0, and 1.0, for Ca1P0, Ca1P1, Ca2P0, and Ca2P1, respectively. This indicated that crop residues likely contributed to base saturation in the low liming level. The higher Ca + Mg + K level with crop residues returned showed the importance of crop residues as a source of nutrients in low fertilization farming systems. In these systems, lime and mineral fertilization are not readily available. The return of crop residues to the soil resulted in an increase in K levels at both liming levels. Within each liming level, the return of crop residues resulted in decreasing levels of extractable P. The lower P contents of the treatments with residues returned may be related to higher crop yields and consequently higher removal by crops. Corn yields in the field experiment (1979) averaged 1.5 times higher with residues returned than with residues removed. In contrast to P, Zn levels were slightly higher when crop residues were returned to the soil.

Both lime and return of crop residue increased corn yield in the field experiment (Brasil, 1980). Although the

differences were small, C, TKN, and C:N ratio tended to be higher when residues were returned. The C:N ratio was higher with liming level 2 (Ca2) than with liming level 1 (Ca1). Higher yields and thus more crop residues could explain these trends. Cultivation of the virgin soil increased or maintained the soil C levels. The TKN content decreased or was at most maintained. The C:N ratio increased in all cropped treatments as compared with the virgin soil. The fertility level of the "native grassland plowed under" (NGPU) treatment was below that of the virgin soil. This was likely due to lack of mineral fertilization and crop residues to replenish nutrient reserves. Carbon dioxide evolution from the original six soil samples over a 65 day period is shown in Fig. 4.2.

Analysis of variance revealed highly significant differences in  $\text{CO}_2$  evolved between fertility programs, at both 30 and 100 days (Table 4.8). The one degree of freedom contrasts showed highly significant differences, at either 30 or 100 day periods, between the virgin soil and the NGPU treatment, and between the virgin soil and the cropped treatments. Within each liming level (Ca1, Ca2), there was a trend toward higher  $\text{CO}_2$  evolution with crop residues returned to soil (P1) than when removed (P0); the difference was significant only for liming level 1. Clearing the native cerrado trees and shrubs and plowing the native grassland under (NGPU), resulted in  $\text{CO}_2$  evolution levels

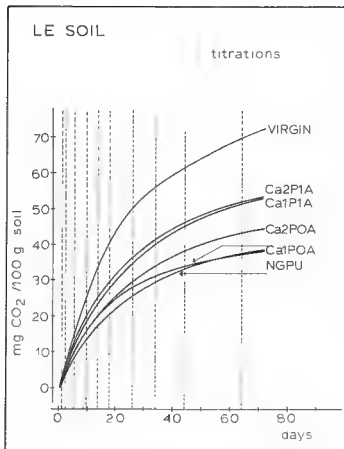


Figure 4.2 - Accumulated CO<sub>2</sub> evolution curves from the original LE soils experiment.

Table 4.8 - Accumulated  $\text{CO}_2$  evolved from the original LE soils at 30 and 100 days, as calculated from the regression equations.

| Fertility program |      | 30 days                                  | 100 days |
|-------------------|------|------------------------------------------|----------|
|                   |      | ----- mg $\text{CO}_2$ /100 g soil ----- |          |
| Ca1POA            | 30.6 | 38.0                                     |          |
| Ca1P1A            | 38.9 | 54.7                                     |          |
| Ca2POA            | 32.9 | 44.5                                     |          |
| Ca2P1A            | 40.8 | 51.9                                     |          |
| Virgin            | 54.8 | 70.6                                     |          |
| NGPU              | 28.9 | 39.5                                     |          |

similar to the cropped treatments with residues removed (PO). These results indicate that cultivation in some way altered the organic matter characteristics of the LE virgin soil. Assuming that less  $\text{CO}_2$  evolution reflected a decrease in the more easily oxidizable portion of the organic matter, these findings indicated that cultivation decreased the biologically more active fraction of the LE virgin soil. The removal of crop residues enhanced this trend.

#### Nitrogen Uptake from Plant Residues by Upland Rice

Rice dry matter yield (DM), N content (TKN), N uptake, and  $^{15}\text{N}$  recovery, by plant component, are shown in Tables 4.9 and 4.10, for sorghum and clover residues, respectively.

Table 4.9 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake, and  $^{15}\text{N}$  recovery from sorghum residues added to the LE soil.

| Fertility program | Plant part | Dry matter |                      |           |                          |
|-------------------|------------|------------|----------------------|-----------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake* | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot    | dag kg <sup>-1</sup>     |
| Crop 1            |            |            |                      |           |                          |
| Ca1POA‡           | Grain      | 600        | 1.8                  | 10.5      | 1.5                      |
|                   | Top        | 2603       | 1.1                  | 28.1      | 4.1                      |
|                   | Root       | 1080       | 1.2                  | 12.9      | 2.1                      |
|                   | Total      | 4283       |                      | 51.5      | 8.7                      |
| Ca1P1A            | Grain      | 1210       | 1.6                  | 19.1      | 2.5                      |
|                   | Top        | 3460       | 1.3                  | 30.1      | 4.2                      |
|                   | Root       | 1063       | 0.9                  | 13.6      | 2.1                      |
|                   | Total      | 5733       |                      | 62.8      | 8.8                      |
| Ca2POA            | Grain      | 673        | 1.9                  | 12.6      | 1.6                      |
|                   | Top        | 2893       | 1.2                  | 34.7      | 4.7                      |
|                   | Root       | 827        | 1.5                  | 12.4      | 1.8                      |
|                   | Total      | 4393       |                      | 69.7      | 8.1                      |
| Ca2P1A            | Grain      | 1200       | 1.7                  | 20.3      | 2.6                      |
|                   | Top        | 1070       | 1.0                  | 31.1      | 4.4                      |
|                   | Root       | 2987       | 1.3                  | 14.2      | 2.2                      |
|                   | Total      | 5257       |                      | 76.6      | 9.2                      |
| Virgin            | Grain      | 1363       | 1.8                  | 24.1      | 2.9                      |
|                   | Top        | 1267       | 1.2                  | 38.3      | 4.9                      |
|                   | Root       | 3217       | 1.2                  | 15.6      | 2.1                      |
|                   | Total      | 5847       |                      | 78.0      | 9.9                      |
| NGPU              | Grain      | 847        | 1.6                  | 13.9      | 1.8                      |
|                   | Top        | 2437       | 0.8                  | 19.0      | 2.8                      |
|                   | Root       | 640        | 1.2                  | 7.6       | 1.3                      |
|                   | Total      | 3924       |                      | 40.5      | 5.9                      |
| Crop 2            |            |            |                      |           |                          |
| Ca1POA            | Grain      | 2453       | 1.2                  | 28.5      | 3.5                      |
|                   | Top        | 2903       | 0.4                  | 10.2      | 1.3                      |
|                   | Root       | 980        | 0.7                  | 6.6       | 0.8                      |
|                   | Total      | 6336       |                      | 45.3      | 5.6                      |

Table 4.9-continued.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Ca1P1A            | Grain      | 2437       | 1.2                  | 28.0                  | 3.5                      |
|                   | Top        | 3157       | 0.4                  | 11.7                  | 1.3                      |
|                   | Root       | 917        | 0.8                  | 6.9                   | 0.9                      |
|                   | Total      | 6511       |                      | 46.6                  | 5.7                      |
| Ca2POA            | Grain      | 1673       | 1.2                  | 19.2                  | 2.6                      |
|                   | Top        | 2307       | 0.4                  | 9.5                   | 1.3                      |
|                   | Root       | 650        | 0.8                  | 5.2                   | 0.7                      |
|                   | Total      | 4630       |                      | 33.9                  | 4.6                      |
| Ca2P1A            | Grain      | 2153       | 1.2                  | 26.1                  | 3.5                      |
|                   | Top        | 2753       | 0.3                  | 9.1                   | 1.2                      |
|                   | Root       | 830        | 0.8                  | 6.2                   | 0.8                      |
|                   | Total      | 5736       |                      | 41.4                  | 5.5                      |
| Virgin            | Grain      | 2743       | 1.3                  | 36.2                  | 3.8                      |
|                   | Top        | 2933       | 0.4                  | 12.6                  | 1.3                      |
|                   | Root       | 1463       | 0.8                  | 11.1                  | 1.2                      |
|                   | Total      | 7139       |                      | 59.9                  | 6.3                      |
| NGPU              | Grain      | 1877       | 1.2                  | 22.3                  | 3.0                      |
|                   | Top        | 2680       | 0.4                  | 9.6                   | 1.3                      |
|                   | Root       | 1000       | 0.6                  | 6.3                   | 0.8                      |
|                   | Total      | 5557       |                      | 38.2                  | 5.1                      |

\* 52.52 mg N added as sorghum residue (3.729 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

† See Table 3.2 for description of field treatments.

Table 4.10 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake, and  $^{15}\text{N}$  recovery from clover residues added to the LE soil.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Crop 1            |            |            |                      |                       |                          |
| Ca1POA†           | Grain      | 3423       | 2.3                  | 77.7                  | 12.0                     |
|                   | Top        | 4690       | 1.0                  | 47.4                  | 8.0                      |
|                   | Root       | 1353       | 1.4                  | 18.5                  | 2.9                      |
|                   | Total      | 9466       |                      | 143.6                 | 22.9                     |
| Ca1P1A            | Grain      | 2773       | 1.8                  | 50.7                  | 8.6                      |
|                   | Top        | 5493       | 1.0                  | 56.6                  | 9.7                      |
|                   | Root       | 1607       | 1.4                  | 21.7                  | 3.4                      |
|                   | Total      | 9873       |                      | 129.0                 | 21.7                     |
| Ca2POA            | Grain      | 2577       | 1.7                  | 43.0                  | 7.5                      |
|                   | Top        | 4790       | 1.2                  | 58.9                  | 9.9                      |
|                   | Root       | 1163       | 1.5                  | 17.8                  | 2.9                      |
|                   | Total      | 8530       |                      | 119.7                 | 20.3                     |
| Ca2P1A            | Grain      | 3093       | 1.8                  | 56.0                  | 8.4                      |
|                   | Top        | 4630       | 1.2                  | 53.2                  | 8.8                      |
|                   | Root       | 1327       | 1.3                  | 16.6                  | 2.6                      |
|                   | Total      | 9050       |                      | 125.8                 | 19.8                     |
| Virgin            | Grain      | 3660       | 1.8                  | 67.0                  | 10.1                     |
|                   | Top        | 5003       | 1.4                  | 69.0                  | 10.4                     |
|                   | Root       | 1970       | 1.2                  | 23.2                  | 3.2                      |
|                   | Total      | 10633      |                      | 159.2                 | 23.7                     |
| NGPU              | Grain      | 3223       | 1.9                  | 60.9                  | 11.3                     |
|                   | Top        | 4867       | 1.0                  | 48.7                  | 9.2                      |
|                   | Root       | 1403       | 1.2                  | 17.3                  | 3.0                      |
|                   | Total      | 9493       |                      | 126.9                 | 23.5                     |
| Crop 2            |            |            |                      |                       |                          |
| Ca1POA            | Grain      | 2150       | 1.6                  | 34.8                  | 3.6                      |
|                   | Top        | 2743       | 0.4                  | 12.1                  | 1.2                      |
|                   | Root       | 707        | 0.8                  | 5.9                   | 0.6                      |
|                   | Total      | 5600       |                      | 52.8                  | 5.4                      |

Table 4.10-continued.

| Fertility program | Plant part | Dry matter |                      |                       |                          |
|-------------------|------------|------------|----------------------|-----------------------|--------------------------|
|                   |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|                   |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Ca1P1A            | Grain      | 1973       | 1.3                  | 24.9                  | 2.5                      |
|                   | Top        | 3063       | 0.5                  | 14.7                  | 1.4                      |
|                   | Root       | 943        | 0.7                  | 6.5                   | 0.7                      |
|                   | Total      | 5979       |                      | 46.1                  | 4.6                      |
| Ca2POA            | Grain      | 1373       | 1.3                  | 17.7                  | 1.9                      |
|                   | Top        | 2700       | 0.5                  | 12.1                  | 1.4                      |
|                   | Root       | 810        | 0.9                  | 7.2                   | 0.9                      |
|                   | Total      | 4883       |                      | 37.0                  | 4.2                      |
| Ca2P1A            | Grain      | 1677       | 1.2                  | 20.6                  | 1.9                      |
|                   | Top        | 2667       | 0.5                  | 12.8                  | 1.5                      |
|                   | Root       | 930        | 0.8                  | 7.8                   | 0.9                      |
|                   | Total      | 5274       |                      | 41.2                  | 4.3                      |
| Virgin            | Grain      | 2927       | 1.4                  | 41.6                  | -*                       |
|                   | Top        | 3273       | 0.4                  | 12.8                  | 1.2                      |
|                   | Root       | 1213       | 0.8                  | 10.2                  | 0.9                      |
|                   | Total      | 7413       |                      | 64.6                  | -*                       |
| NGPU              | Grain      | 1760       | 1.2                  | 21.8                  | 2.4                      |
|                   | Top        | 2857       | 0.4                  | 10.3                  | 1.1                      |
|                   | Root       | 870        | 0.7                  | 6.4                   | 0.7                      |
|                   | Total      | 5487       |                      | 38.5                  | 4.2                      |

<sup>+</sup> 221.92 mg N added as sorghum residue (2.187 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

<sup>‡</sup> See Table 3.2 for description of management programs.

\* Insufficient material available for analysis.

Highly significant differences in yield of tops and grain were found between residues. No differences in root yield was found between residues. Combining both crops, the average yields for the whole plant were 5445 and 7640 mg/pot with sorghum and clover residue, respectively. With sorghum residue, yields for the whole plant were 4906 and 5985 mg/pot in the first and second crop, respectively; with clover residue, yields were 3508 and 5773 mg/pot, in the first and second crop, respectively. The increase in yield with sorghum residue in the second crop could be the effect of a higher decomposition rate of the sorghum residue during the late first crop/early second crop time period, while the clover residue decomposed at a high rate earlier in the first crop. Different decomposition rates were due to the C:N ratio of the residues, which were 80:1 for sorghum and 18:1 for clover. Chichester et al. (1975) found that net N mineralization was delayed by 2 to 10 weeks when materials high in C were added to the soil.

The N recovery in the whole plant, with both residues, was higher in the first than in the second crop. In the first crop, N recoveries averaged 8.4 and 22.0% for sorghum and clover residue, respectively. In the second crop, N recoveries averaged 5.5 and 4.5% for sorghum and clover residues, respectively. There was a higher N recovery by grain in the second crop with sorghum residue (average of 3.3%) than with clover residue (average of 2.5%). Similar

to the yield results discussed above, higher N recovery by the sorghum residue in the second crop in the whole plant, and especially in grain, suggests a more active sorghum residue decomposition at the late first crop/early second crop time period. Due to the sorghum residue mineralization delay, the N that went to the grain in the first crop likely was taken up in the beginning of the growing cycle, when proportionally more unlabelled N was available. When reproductive growth began, N uptake from the soil was expected to decrease and internal reutilization became the main mechanism for providing N to grain (Salisbury and Ross, 1978).

The following one degree of freedom contrasts involving fertility programs were tested for N recovery: 1) virgin soil vs. NGPU; 2) virgin soil vs. cropped treatments; 3) NGPU vs. cropped treatments; 4) with and without residues returned in liming level 1; and 5) with and without residues returned in liming level 2. These tests were performed for each plant part, for the whole plant, and for the returnable portion (top + root). Also, the sum of N recoveries in both crops was tested for the whole plant and for the returnable portion. With sorghum residue, N recovery for the first crop in the whole plant was significantly different in all contrasts tested; it was higher for the virgin soil than for either the NGPU or cropped treatments and higher when crop residues were returned in

both lime levels. In the second crop, N recovery for the virgin soil was larger than either NGPU or the cropped treatments. In both crops, N recoveries differed little between lime levels. In the returnable portion, N recovery from sorghum residue, in the first crop and with both crops combined, was significantly higher for the virgin soil than for either the NGPU treatment or the cropped treatments. No differences were found in the second crop. With clover residue, N recovery in the whole plant and root + top portion was not significantly different, in both crops, for all the contrasts tested between field treatments.

Comparisons between field treatments for each plant part did not show consistent trends, which precluded reliable conclusions. Examination of the fertility status of the original soil samples did not explain the higher yields obtained with the virgin soil. Soil fertility levels of the virgin and NGPU treatments were clearly below those of the cropped treatments (Table 4.7). Yet the yields from the virgin soils were higher than yields from either the NGPU or cropped treatments for both residues.

For each plant part, significant correlations were found between yield and N recovery. These correlations suggested that yields were dependent upon N availability from decomposing plant residues, and consequently field treatments affected N availability of plant residues. These changes in N availability from plant residues were

attributed to changes in availability of the organic N. The cultivation process likely led to more stable forms of N in soil. Therefore, similar C:N ratio values between field treatments did not necessarily imply similar N availability.

Nitrogen Remaining in the Soil and Unaccounted for  
After Growth of Two Upland Rice Crops

There was a significantly larger proportion of the added residue-N remaining in soil with sorghum residue (69%) than with clover residue (55%). Correspondingly, there was greater plant uptake from clover (26%) than sorghum residue (14%). These values were significantly correlated. The analysis of variance showed highly significant differences between residues for both N remaining in soil and that taken up by plants. No difference between residues was found for the unaccounted for N portion. Within each residue, no significant correlations were found between N remaining in soil and plant uptake. These results suggest that the proportions of N recovered by rice and N remaining in the soil were related to the N content of the residues (0.53 dag kg<sup>-1</sup> for sorghum and 2.22 dag kg<sup>-1</sup> for clover). The magnitude of the N losses (unaccounted for N) were attributed to the environmental conditions prevailing in the glasshouse experiment. The reasons for this conclusion are because N losses: 1) were not correlated with residue type; 2) were not significantly different between residues; and 3) were not significantly different between field treatments. The environmental conditions more likely to

Table 4.11 Nitrogen Remaining in soil, N recovered in two crops in the whole rice plant, N unaccounted for etc. soil, TNH and C/N ratio in the original Nk soils samples and at the end of the glasshouse experiment

| Fertility Program <sup>1</sup> | Residue | N                 |                      |                 | TNH                                |                              | C/N ratio                          |                              |
|--------------------------------|---------|-------------------|----------------------|-----------------|------------------------------------|------------------------------|------------------------------------|------------------------------|
|                                |         | Remaining in soil | Recovered in 2 crops | unaccounted for | Original soil samples <sup>2</sup> | End of glasshouse experiment | Original soil samples <sup>2</sup> | End of glasshouse experiment |
|                                |         |                   |                      |                 |                                    |                              |                                    |                              |
| mg kg <sup>-1</sup>            |         |                   |                      |                 |                                    |                              |                                    |                              |
| Ca1P0A                         | Sorghum | 68.4              | 19.1                 | 18.4            | 0.12                               | 0.12                         | 11.8                               | 1.2                          |
|                                | Clover  | 57.0              | 28.4                 | 14.6            |                                    | 0.13                         |                                    | 0.2                          |
| Ca1P1A                         | Sorghum | 70.0              | 14.4                 | 19.5            | 0.13                               | 0.13                         | 12.7                               | 10.3                         |
|                                | Clover  | 51.4              | 26.3                 | 22.5            |                                    | 0.12                         |                                    | 10.6                         |
| Ca2P0A                         | Sorghum | 70.1              | 12.8                 | 17.1            | 0.11                               | 0.11                         | 12.1                               | 11.0                         |
|                                | Clover  | 59.9              | 24.6                 | 15.5            |                                    | 0.13                         |                                    | 10.3                         |
| Ca2P1A                         | Sorghum | 68.9              | 14.6                 | 16.2            | 0.12                               | 0.12                         | 13.7                               | 11.1                         |
|                                | Clover  | 51.1              | 24.0                 | 24.8            |                                    | 0.12                         |                                    | 10.6                         |
| Virgin                         | Sorghum | 66.8              | 16.1                 | 17.1            | 0.13                               | 0.13                         | 9.4                                | 11.5                         |
|                                | Clover  | 53.9              |                      |                 |                                    | 0.13                         |                                    | 11.3                         |
| NkPL                           | Sorghum | 68.1              | 11.0                 | 20.7            | 0.11                               | 0.11                         | 10.3                               | 10.9                         |
|                                | Clover  | 56.8              | 27.6                 | 16.1            |                                    | 0.12                         |                                    | 11.0                         |

<sup>1</sup> Same data as Table 4.1.

<sup>2</sup> See Table 3.2

have affected N losses were residue particle size, soil structure deterioration and low water tension level.

The different rates of decomposition and similar N losses between residues explains the significant difference in N uptake by rice. Consequently, the N remaining in soil was also significantly different between residues.

For both residues, the significant differences in TKN between the original soils were maintained at the end of the experiment. With sorghum residue, soil TKN did not change at the end of the glasshouse experiment, as compared with the original soil values; clover residue showed a trend toward increasing or maintaining TKN levels. This showed that the sorghum residue essentially did not alter the TKN status of the soil while the clover residue had the potential to change the original TKN values.

The field treatments were compared through the following one degree of freedom contrasts: 1) virgin soil vs. cropped treatments; 2) virgin soil vs. NGPU; 3) liming level 1 (Ca1) vs. liming level 2 (Ca2); and 4) in each liming level, the treatment with crop residues removed (P0) vs. crop residues returned (P1).

With clover residue, in both liming levels, the N remaining in soil was significantly greater when crop residues were removed (59%) than where the crop residues were returned (51%). Nitrogen losses were greater for the treatments with residues returned (24%) than for the

treatments with residues removed (15%). Plant N recoveries were not affected by returning residues to the field treatments. This implies that the smaller proportion of N remaining in soil with crop residues returned did not result in proportional increase in N plant uptake, but a proportional increase in N losses. These results indicate that, in the glasshouse study, plant N recovery levels were linked to the type of residue used. The N remaining in soil was a measure of the inability of the soil to decompose the plant residues, which varied among the field treatments. With sorghum residue, none of the contrasts tested was significant.

A significant difference between liming levels was found with clover residue for the N recovered in plants, which averaged 27% for liming level 1 (Ca<sup>1</sup>) and 24% for liming level 2 (Ca<sup>2</sup>). Even though the soil fertility levels could not explain this result alone, the higher liming level showed higher C:N ratio, lower TKN, lower K, and lower P levels. Phosphorus is the most serious limiting nutrient in these soils. These are conditions that would favor slower decomposition rates.

Considering all parameters tested, a virtual absence of significant differences between field treatments with sorghum residue was observed. This finding was attributed to the low N content and low decomposition rate of the sorghum residue.

### Virgin Soils

#### Original Soil Sample Characterization

Two virgin Ultisols from Florida, Dothan, and Troup, were included in the glasshouse study and compared to the LA and LE virgin Oxisols. The C and N contents of the Ultisols were lower than those of the Oxisols (Table 4.12). The C:N ratio of the four soils ranged from 9.4 (LE) to 13.9 (Dothan). The ratio of the sum of Ca, Mg, and K to Al averaged 0.13 for the Oxisols and 2.6 for the Ultisols, indicating that Al toxicity may be a problem in the virgin Oxisols. The Troup soil, sampled as a virgin soil, showed

Table 4.12 - Selected characteristics of the virgin soils samples used in the glasshouse experiment.

| Soil   | Double acid extractable† |                      |      |      |     |                     |    |    |     |       |
|--------|--------------------------|----------------------|------|------|-----|---------------------|----|----|-----|-------|
|        | pH                       | C <sup>+</sup>       | TKN  | C:N  | Al  | Ca                  | Mg | K  | Zn  | P     |
|        |                          | dag kg <sup>-1</sup> |      |      |     | mg kg <sup>-1</sup> |    |    |     |       |
| LA     | 5.3                      | 1.0                  | 0.08 | 12.4 | 296 | 20                  | 4  | 16 | 0.3 | 1.2   |
| LE     | 5.0                      | 1.2                  | 0.13 | 9.4  | 588 | 28                  | 12 | 24 | 0.2 | 2.4   |
| Dothan | 5.5                      | 0.8                  | 0.06 | 13.9 | 216 | 208                 | 72 | 44 | 0.5 | 8.0   |
| Troup  | 6.4                      | 0.5                  | 0.04 | 11.4 | 164 | 308                 | 76 | 36 | 5.2 | 152.0 |

\* Walkley-Black method without correction for efficiency.

† Mehlich I extractant.

high Zn and P levels, probably due to contamination from the cultivated field adjacent to the sampled area.

As a group, the virgin soils presented the highest and most homogeneous rates of  $\text{CO}_2$  evolution (Table 4.13 and Fig. 4.3). The analysis of variance for the 30-day period of  $\text{CO}_2$  evolution (Appendix 3) showed a probability of 0.07 for no difference between soils. For the 100-day period, the probability was 0.06. The contrasts between LA versus LE soil, Dothan versus Troup, and the two Oxisols against the two Ultisols were all non-significant. The C, TKN, and C:N ratio of these soils (Table 4.12) were significantly different even though the amounts of  $\text{CO}_2$  evolved were not. This suggests that the C components of the soil organic matter may vary structurally between soils.

Table 4.13 - Accumulated  $\text{CO}_2$  evolved from original virgin soils at 30 and 100 days, as calculated from regression equations.

| Soil                                     | 30 days | 100 days |
|------------------------------------------|---------|----------|
| ----- mg $\text{CO}_2$ /100 g soil ----- |         |          |
| LA                                       | 50.1    | 63.9     |
| LE                                       | 54.8    | 70.6     |
| Dothan                                   | 49.4    | 60.2     |
| Troup                                    | 38.7    | 53.9     |

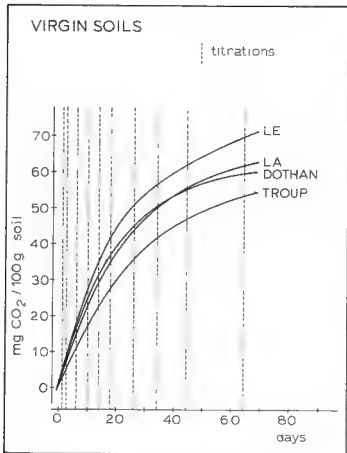


Figure 4.3 - Accumulated CO<sub>2</sub> evolution curves from the original virgin soils.

### Nitrogen Uptake from Plant Residues by Upland Rice

Plant yield varied significantly between soils. Similarly, yield of plant parts was significantly different between soils, crops, and residues. Plants grown in the virgin LE soil showed the highest yields throughout the glasshouse experiment (Tables 4.14 and 4.15). The LE soil had the highest TKN level among the virgin soils. Also, a positive correlation was found between yield and TKN of the original soils. Therefore, the highest yields in the LE soil could be attributed to the higher soil N availability, and consequently better conditions for plant residue decomposition. In considering N uptake and  $^{15}\text{N}$  recovery, there was a clear trend between soils in the first crop for both residues. The values of N uptake and  $^{15}\text{N}$  recovery decreased in the following order: LE, LA and Dothan, Troup. Also, rice yields in the first crop were positively correlated with N uptake and  $^{15}\text{N}$  recovery. In the second crop, rice yields were similarly correlated with N uptake and  $^{15}\text{N}$  recovery, but the Oxisols as a group showed higher values than the Ultisols. This change in results in the second crop was due to a lower N uptake and  $^{15}\text{N}$  recovery with the Dothan soil as compared to the LA soil.

### Nitrogen Remaining in Soil and Unaccounted for After Growth of Two Upland Rice Crops

More N was recovered in plants and less remained in soil with clover residue than with sorghum residue. With sorghum residue, the average of the N remaining in the four

Table 4.14 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake and  $^{15}\text{N}$  recovery from sorghum residues added to the virgin soils.

| Soil   | Plant part | Dry Matter |                      |                       |                          |
|--------|------------|------------|----------------------|-----------------------|--------------------------|
|        |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|        |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Crop 1 |            |            |                      |                       |                          |
| LA     | Grain      | 387        | 1.8                  | 7.0                   | 0.9                      |
|        | Top        | 1830       | 1.3                  | 23.4                  | 3.7                      |
|        | Root       | 1413       | 0.9                  | 12.6                  | 2.1                      |
|        | Total      | 3630       |                      | 43.0                  | 6.7                      |
| LE     | Grain      | 1363       | 1.8                  | 24.1                  | 2.9                      |
|        | Top        | 1267       | 1.2                  | 38.3                  | 4.9                      |
|        | Root       | 3217       | 1.2                  | 15.6                  | 2.1                      |
|        | Total      | 5847       |                      | 78.0                  | 9.9                      |
| Dothan | Grain      | 513        | 1.6                  | 8.4                   | 1.2                      |
|        | Top        | 2337       | 1.1                  | 26.4                  | 3.4                      |
|        | Root       | 750        | 1.4                  | 10.2                  | 1.6                      |
|        | Total      | 3600       |                      | 45.0                  | 6.2                      |
| Troup  | Grain      | 97         | 2.0                  | 1.9                   | 0.3                      |
|        | Top        | 1083       | 1.2                  | 13.3                  | 2.6                      |
|        | Root       | 354        | 1.2                  | 4.4                   | 1.1                      |
|        | Total      | 1534       |                      | 19.6                  | 4.0                      |
| Crop 2 |            |            |                      |                       |                          |
| LA     | Grain      | 2083       | 1.2                  | 25.8                  | 3.3                      |
|        | Top        | 2803       | 0.4                  | 10.1                  | 1.3                      |
|        | Root       | 1863       | 0.7                  | 13.8                  | 1.8                      |
|        | Total      | 6748       |                      | 49.7                  | 6.4                      |
| LE     | Grain      | 2743       | 1.3                  | 36.2                  | 3.8                      |
|        | Top        | 2933       | 0.4                  | 12.6                  | 1.3                      |
|        | Root       | 1463       | 0.8                  | 11.1                  | 1.2                      |
|        | Total      | 7139       |                      | 59.9                  | 6.3                      |

Table 4.14-continued.

| Soil   | Plant part | Dry Matter |                      |                       |                          |
|--------|------------|------------|----------------------|-----------------------|--------------------------|
|        |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|        |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Dothan | Grain      | 813        | 1.3                  | 10.7                  | 1.6                      |
|        | Top        | 2497       | 0.5                  | 13.2                  | 1.5                      |
|        | Root       | 1007       | 1.0                  | 9.8                   | 2.0                      |
|        | Total      | 4317       |                      | 33.7                  | 5.1                      |
| Troup  | Grain      | 980        | 1.2                  | 11.7                  | 2.3                      |
|        | Top        | 1667       | 0.5                  | 8.2                   | 1.5                      |
|        | Root       | 623        | 0.9                  | 5.4                   | 1.0                      |
|        | Total      | 3270       |                      | 25.3                  | 4.8                      |

<sup>+</sup> 52.52 mg N added as sorghum residue (3.729 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

Table 4.15 - Rice dry matter yield, total Kjeldahl N (TKN), N uptake and  $^{15}\text{N}$  recovery from clover residues added to the virgin soils.

| Soil   | Plant part | Dry Matter |                      |                       |                          |
|--------|------------|------------|----------------------|-----------------------|--------------------------|
|        |            | Yield      | TKN                  | N uptake <sup>+</sup> | <sup>15</sup> N recovery |
|        |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Crop 1 |            |            |                      |                       |                          |
| LA     | Grain      | 1547       | 1.6                  | 25.2                  | 4.4                      |
|        | Top        | 3573       | 1.5                  | 51.8                  | 7.9                      |
|        | Root       | 2510       | 1.1                  | 26.9                  | 4.2                      |
|        | Total      | 7630       |                      | 103.9                 | 16.5                     |
| LE     | Grain      | 3660       | 1.8                  | 67.0                  | 10.1                     |
|        | Top        | 5003       | 1.4                  | 69.0                  | 10.4                     |
|        | Root       | 1970       | 1.2                  | 23.2                  | 3.2                      |
|        | Total      | 10633      |                      | 159.2                 | 23.7                     |
| Dothan | Grain      | 1897       | 1.7                  | 32.4                  | 5.3                      |
|        | Top        | 4917       | 1.1                  | 55.1                  | 9.3                      |
|        | Root       | 1820       | 1.5                  | 27.8                  | 4.5                      |
|        | Total      | 8634       |                      | 115.3                 | 19.1                     |
| Troup  | Grain      | 597        | 1.9                  | 11.0                  | 2.0                      |
|        | Top        | 2333       | 1.9                  | 45.3                  | 2.4                      |
|        | Root       | 830        | 1.6                  | 15.5                  | 8.7                      |
|        | Total      | 3760       |                      | 69.8                  | 13.1                     |
| Crop 2 |            |            |                      |                       |                          |
| LA     | Grain      | 1653       | 1.4                  | 27.9                  | 2.4                      |
|        | Top        | 2690       | 0.4                  | 11.3                  | 1.2                      |
|        | Root       | 1340       | 0.8                  | 10.2                  | 1.1                      |
|        | Total      | 5683       |                      | 49.4                  | 4.7                      |
| LE     | Grain      | 2927       | 1.4                  | 41.6                  | -†                       |
|        | Top        | 3273       | 0.4                  | 12.8                  | 1.2                      |
|        | Root       | 1213       | 0.8                  | 10.2                  | 0.9                      |
|        | Total      | 7413       |                      | 64.6                  | -†                       |

Table 4.15-continued.

| Soil   | Plant part | Dry Matter |                      |                       |                          |
|--------|------------|------------|----------------------|-----------------------|--------------------------|
|        |            | Yield      | TKN                  | N uptake <sup>†</sup> | <sup>15</sup> N recovery |
|        |            | mg/pot     | dag kg <sup>-1</sup> | mg/pot                | dag kg <sup>-1</sup>     |
| Dothan | Grain      | 574        | 1.4                  | 7.9                   | 0.9                      |
|        | Top        | 1640       | 0.7                  | 11.5                  | 1.5                      |
|        | Root       | 663        | 1.3                  | 8.8                   | 1.3                      |
|        | Total      | 2877       |                      | 28.2                  | 3.7                      |
| Troup  | Grain      | 1380       | 1.4                  | 18.8                  | 2.8                      |
|        | Top        | 1963       | 0.7                  | 13.3                  | 2.0                      |
|        | Root       | 557        | 1.0                  | 5.3                   | 0.8                      |
|        | Total      | 3900       |                      | 37.4                  | 5.6                      |

<sup>†</sup> 221.92 mg N added as sorghum residue (2.187 dag <sup>15</sup>N kg<sup>-1</sup>) prior to planting.

<sup>‡</sup> Insufficient material available for analysis.

Table 4-16 Nitrogen remaining in soil, N recovered in two crops in the whole rice plant, N unaccounted for, and soil C:N ratio in the original virgin soil samples and at the end of the glasshouse experiment.

| Soil   | Residue | N                    |                            |                    | TKN                          |                                    | C:N ratio                    |                                    |
|--------|---------|----------------------|----------------------------|--------------------|------------------------------|------------------------------------|------------------------------|------------------------------------|
|        |         | Remaining<br>in soil | Recovered<br>in 2<br>crops | Unaccounted<br>for | Origina.<br>soil<br>samples* | End of<br>glasshouse<br>experiment | Origina.<br>soil<br>samples* | End of<br>glasshouse<br>experiment |
|        |         | g                    |                            |                    |                              |                                    | dag kg <sup>-1</sup>         |                                    |
| LA     | Sorghum | 54.0                 | 13.2                       | 52.8               | 0.08                         | 0.07                               | 13.7                         | 12.4                               |
|        | Clover  | 45.0                 | 21.3                       | 29.5               |                              | 0.08                               |                              | 11.7                               |
| LC     | Sorghum | 66.8                 | 16.1                       | 17.1               | 0.13                         | 0.13                               | 9.4                          | 11.5                               |
|        | Clover  | 53.9                 | —†                         | —†                 |                              | 0.13                               |                              | 11.3                               |
| Jothan | Sorghum | 62.5                 | 11.4                       | 26.1               | 0.06                         | 0.06                               | 13.9                         | 15.2                               |
|        | Clover  | 52.7                 | 22.9                       | 24.5               |                              | 0.07                               |                              | 13.2                               |
| Troup  | Sorghum | 57.9                 | 8.8                        | 33.4               | 0.04                         | 0.05                               | 11.4                         | 10.5                               |
|        | Clover  | 47.9                 | 18.6                       | 33.5               |                              | 0.05                               |                              | 9.8                                |

\* Same data as Table 4-12.

† Material unavailable for analysis.

virgin soils was 60% and the average of the N plant recovery was 12%. With clover residue, these values were 51% and 21%. The N recovered in plants was significantly different only between residues. Differences between soils were significant only for N remaining in the soil. With sorghum residue, the N remaining in soil was highest for the LE soil and lowest for the Troup soil. With clover residue, the N remaining varied little between soils. The results suggested that the differences in N taken up by plants were related to the TKN in the original soils and the N content of the added plant residues. The range of plant N uptake was from 9% with sorghum residue in the Troup soil to 23% with clover residue in the Dothan soil. The difference between initial and final soil TKN was not significant with sorghum residue, but highly significant with clover residue (Appendix 2). This indicated that the sorghum residue did not provide enough N to change the soil N pool, while the legume residue increased it significantly.

There was no difference between residues regarding N losses (unaccounted for N), which averaged 26 and 29% with sorghum and clover residue, respectively. The unaccounted for N was not correlated with residue type. The unaccounted for N was negatively correlated with TKN of original soils which was significantly different between soils (Table 4.12). The values found in the unaccounted for N between soils were 31, 17, 25, and 34% for the LA, LE, Dothan and

Troup soils, respectively. Therefore, it was possible to conclude that the size of the N losses was related to soil or experimental environmental conditions, while the N plant recovery depended upon plant residue N content.

## CHAPTER 5 CONCLUSIONS

### CO<sub>2</sub> Evolution

In the experiment with the LA soil, the positive correlation between CO<sub>2</sub> evolved and the C:N ratios indicated that cultivation, but not specific fertility programs, altered C components of soil organic matter. In the LE soil experiment, CO<sub>2</sub> evolution reflected the crop residue management. Independent of lime levels, return of crop residues resulted in the smallest decreases of CO<sub>2</sub> evolution, as compared with the virgin soil. This was due to the annual return of easily decomposable C compounds to the soil organic matter. This replenishment did not happen where the crop residues were removed or where no mineral fertilization was used (NGPU treatment). The CO<sub>2</sub> evolved from the four virgin soils was directly proportional to their C and N contents.

### Residue and Crop Effects

Yield and N recovery for grain in the second crop with sorghum residue were higher than with legume residue. This

suggested that, in the first crop, more net N mineralization occurred after maximum N uptake. This was attributed to a delay in decomposition of sorghum residue relative to the clover residue. The cause for this longer turnover period was lower N content of sorghum residue. The higher N recovery in grain with sorghum residue in the second crop was likely due to the N reutilization mechanism of the plant (Salisbury and Ross, 1978). Nitrogen taken up early in the cycle is stored in leaves and later transferred to the grain. With the clover residue, a higher decomposition rate early in the first crop provided more labelled N in the first than in the second crop.

The high C:N ratio of sorghum residue and its longer immobilization-mineralization turnover period led to consideration of the broader problem of burning crop residues. Although this practice results in losses of N and S, it is the only management alternative in low input energy/multiple cropping farming systems to deal with large biomass surpluses. Time usually is not enough to allow high C:N ratio residues to decompose. In the cerrado region, a long dry season does not permit proper decomposition of grass crop residues which are frequently burned. Double cropping grass and legume crops in one rainy season has been successfully tried, but more research is required on crop residue management.

### Soil Type and Field Treatment Effects

Recovery of  $^{15}\text{N}$  from either residue in the first crop for the LA soil was higher for the high fertilization treatments than for the virgin soil. In the second crop with clover residue,  $^{15}\text{N}$  recovery for the low fertilization treatment was lower than for the two high fertilization treatments. This was attributed to a lower nutrient reserve in the low fertilization treatment, and probably a biologically less active form of organic matter, as seen from the  $\text{CO}_2$  evolution data.

In the LE soil experiment, the relatively high yields of both rice crops for the virgin soil and NGPU treatment, as compared with the cropped treatments, could not be explained by the characteristics of the original soil samples. Yields and  $^{15}\text{N}$  recovery were found to be correlated, showing the interdependence of yield and N supplied by plant residues. This behavior is not found in this cerrado soil in the field, where the productivity increases from clearing to generally the fourth year of cultivation. It is known that the more complete the removal of root debris during clearing operations, the sooner productivity will increase (Brasil, 1979b). For the glasshouse experiment, all the samples were completely free of root debris which could partially explain the results. Also, the nature of N attachment to the organic matter

macromolecule was likely changed by cultivation. In this way, the cultivation process could have led to more stable, i.e., less available forms of soil N. Studies have found (Dormaar and Pitman, 1979; Allen et al., 1973) that cultivation modified the chemical structure of soil organic matter and that N incorporated to the organic matter became increasingly stable and was not readily mineralizable. Rodriguez and Perez (1977) found that the N availability decreased with successive rice cultivation cycles due to increased polymerization of humic substances.

In the LE field experiment, with sorghum residue, the return of crop residues in the field experiment increased rice yield, N uptake, and  $^{15}\text{N}$  recovery. With clover residue, no noticeable differences in the above parameters were found. Probably, the larger N level of the clover residue overwhelmed differences in the original soils. Rice yields and  $^{15}\text{N}$  recovery generally maintained similar values between the liming levels.

With the cropped treatments of both LA and LE soil experiments, N recovery from added plant residues for the first crop could be considered low. Recovery averaged 25% with clover residue and 9% with sorghum residue. If transformed to absolute amounts, these recoveries represented 110 and 9 kg N ha<sup>-1</sup>, respectively. Recommended N mineral fertilization levels for upland rice in the cerrado region are generally 30 kg N ha<sup>-1</sup> per crop (Brasil, 1979a). Thus,

residues like sorghum or clover could easily provide sufficient N for rice.

### Nitrogen Losses

After two rice crops, the labelled N that was added to the soil as plant residue could have been taken up by plants, left in the soil or lost from the system. Averaging the results for the LA and LE soils and the two Ultisols, the N left in the soil represented 65% of the N of the grass residue and 52% of the N of the legume residue added; for the N recovered in plants, the values were 13% with grass residue and 25% with legume residue. The unaccounted for N differed little between residues, with 22% for grass and 24% for legume residue. For both residues in all soils, the expected significant negative correlation of either plant or soil N versus unaccounted for N was observed, but not a single significant correlation was found between N recovered in plants and N left in soil.

In all soil groups, no significant differences were found between residues for the unaccounted for N. These losses averaged 24 and 25% with sorghum and clover residue, respectively. Losses for the LA and LE soils are similar to those reported by Westerman et al. (1972) for labelled urea and oxamide in field experiments.

In an experiment where all precautions were considered to have been taken to avoid N losses by leaching or denitrification, the losses are considerable. Small losses were expected due to the loss of fine root fragments and soil dust. Denitrification may have been responsible for most of the N loss. Several factors, including soil structure deterioration, small residue particle size, and high residue loading rate would enhance denitrification.

The composite soil samples were collected and dried in a glasshouse at the origin (Brazil), being periodically revolved to speed drying. At the glasshouse experiment site, the samples were transferred to new containers and then weighed for the pot experiment. After the first crop, the soils were sieved to 2 mm particle size for root removal. Each of these procedures would lead to structure deterioration. The plant residues added to soil were ground to pass through a 1 mm sieve. Sain and Broadbent (1977) suggested that the small but significant increase found in the decomposition of longer rice straws (15 - 20 cm compared to 1 - 4 cm) apparently was provided by more favorable aeration for microbial activity. Although the range in particle size in the previous work was very different from what was used here, the 1 mm particle size would likely affect aeration more than a 1 - 4 cm particle size. The combination of evenly distributed fine residue particles with reduced air diffusion due to poor soil structure and a

1% residue rate (weight basis) could make conditions for denitrification possible. Under non-limiting water and temperature conditions, it is reasonable to expect microsites with oxygen deficiency either due to limited air access or to anaerobiosis generated by high residue decomposition rates. Denitrification could then occur due to decline in redox potential in some microsites (Parr and Papendick, 1978), and microbes could utilize nitrate formed during dryer periods preceding irrigations. Simultaneously, mineralization could result in production of ammonia (Yaacob and Blair, 1980) in other microsites with sufficient oxygen supply. Smith (1979) stated that gaseous N losses may be substantial in warm, water-saturated soils containing large amounts of decomposable organic matter. Craswell (1978) found that addition of water to soil cores sealed a relatively large volume of soil from atmospheric  $O_2$  diffusion, resulting in N loss due to denitrification. Shayo-Ngovi (1977) found that, at saturation (zero bar), mature wheat straw residue water content was close to 400% its dry weight. When the residue water potential was about -15 bar, water content was approximately 100% of residue dry weight. Thus, it was possible for anaerobiosis to develop around the residue particles.

### Recommendations for Future Research

These results demonstrate that the soil management programs studied have the potential to affect N recycling from crop residues. Maximization of the N recycling processes requires additional research. Studies using tracer techniques are suggested to: 1) ascertain the biochemistry of N stabilization into humified organic matter, 2) determine the effect of alternate wet and dry cycles on N availability from crop residues under field conditions, and 3) evaluate the effect of crop sequences on N cycling in mono- and multiple cropping systems.

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APPENDIX 1  
STATISTICAL ANALYSIS FOR PLANT TISSUE

Symbols

G R 1: grass (sorghum), root, crop 1  
G R 2: grass (sorghum), root, crop 2  
L R 1: legume (clover), root, crop 1  
L R 2: legume (clover), root, crop 2  
G T 1: grass (sorghum), top, crop 1  
G T 2: grass (sorghum), top, crop 2  
L T 1: legume (clover), top, crop 1  
L T 2: legume (clover), top, crop 2  
G G 1: grass (sorghum), grain, crop 1  
G G 2: grass (sorghum), grain, crop 2  
L G 1: legume (clover), grain, crop 1  
L G 2: legume (clover), grain, crop 2  
5: Ca1POA  
7: Ca1P1A  
9: Ca2POA  
11: Ca2P1A  
13: virgin  
14: NGPU

Table A1.1 - Correlations by plant part by residue, two crops combined.

LA-Acrustox SoilGrain

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N=48

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | 0.42  | -0.89 | -0.22    |
|            | 0.01  | 0.01  | 0.12     |
| MANAGEMENT | -0.11 | -0.04 | -0.10    |
|            | 0.48  | 0.76  | 0.49     |
| YIELD      |       | 0.43  | 0.76     |
|            |       | 0.01  | 0.01     |
| TKN        |       |       | 0.17     |
|            |       |       | 0.24     |

Root

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N=48

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | -0.32 | -0.80 | -0.73    |
|            | 0.02  | 0.01  | 0.01     |
| MANAGEMENT | 0.29  | -0.25 | 0.10     |
|            | 0.04  | 0.09  | 0.50     |
| YIELD      |       | 0.10  | 0.80     |
|            |       | 0.50  | 0.01     |
| TKN        |       |       | 0.63     |
|            |       |       | 0.01     |

Table A1.1-continued.Top

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N=48

|            | YIELD | TKN    | RECOVERY |
|------------|-------|--------|----------|
| CROP       | -0.52 | -0.95  | -0.77    |
|            | 0.01  | 0.01   | 0.01     |
| MANAGEMENT | -0.17 | -0.001 | -0.11    |
|            | 0.24  | 0.99   | 0.46     |
| YIELD      |       | 0.50   | 0.88     |
|            |       | 0.01   | 0.01     |
| TKN        |       |        | 0.81     |
|            |       |        | 0.01     |

LE-Haplustox SoilGrain

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | 0.03  | -0.74 | -0.44    |
|            | 0.83  | 0.01  | 0.01     |
|            | 72    | 72    | 69       |
| MANAGEMENT | 0.07  | -0.09 | 0.01     |
|            | 0.57  | 0.44  | 0.91     |
|            | 72    | 72    | 72       |
| YIELD      |       | 0.11  | 0.84     |
|            |       | 0.36  | 0.01     |
|            |       | 72    | 69       |
| TKN        |       |       | 0.58     |
|            |       |       | 0.01     |
|            |       |       | 69       |

Table A1.1-continued.Root

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | -0.39 | -0.89 | -0.82    |
|            | 0.01  | 0.01  | 0.01     |
|            | 72    | 72    | 72       |
| MANAGEMENT | 0.15  | -0.08 | -0.01    |
|            | 0.21  | 0.52  | 0.92     |
|            | 72    | 72    | 72       |
| YIELD      |       | 0.34  | 0.76     |
|            |       | 0.01  | 0.01     |
|            |       | 72    | 72       |
| TKN        |       |       | 0.82     |
|            |       |       | 0.01     |

Top

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | -0.56 | -0.92 | -0.80    |
|            | 0.01  | 0.01  | 0.01     |
|            | 72    | 72    | 72       |
| MANAGEMENT | -0.02 | 0.01  | 0.01     |
|            | 0.85  | 0.95  | 0.94     |
|            | 72    | 72    | 72       |
| YIELD      |       | 0.59  | 0.89     |
|            |       | 0.01  | 0.01     |
|            |       | 72    | 72       |
| TKN        |       |       | 0.86     |
|            |       |       | 0.01     |
|            |       |       | 72       |

Table A1.1-continued.Virgin soilsGrain

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | 0.19  | -0.84 | -0.19    |
|            | 0.20  | 0.01  | 0.21     |
|            | 48    | 48    | 45       |
| MANAGEMENT | -0.14 | -0.09 | -0.06    |
|            | 0.34  | 0.55  | 0.68     |
|            | 48    | 48    | 45       |
| YIELD      |       | -0.17 | 0.91     |
|            |       | 0.23  | 0.01     |
|            |       | 48    | 45       |
| TKN        |       |       | 0.13     |
|            |       |       | 0.38     |
|            |       |       | 45       |

Root

CORRELATION COEFFICIENTS/ PROB &gt; :R: UNDER HO RHO=0 /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | -0.20 | -0.57 | -0.58    |
|            | 0.17  | 0.01  | 0.01     |
|            | 48    | 48    | 48       |
| MANAGEMENT | -0.56 | 0.45  | -0.02    |
|            | 0.01  | 0.01  | 0.16     |
|            | 48    | 48    | 48       |
| YIELD      |       | -0.13 | 0.78     |
|            |       | 0.38  | 0.01     |
|            |       | 48    | 48       |
| TKN        |       |       | 0.42     |
|            |       |       | 0.01     |
|            |       |       | 48       |

Table A1.1-continued.Top

CORRELATION COEFFICIENTS/ PROB &gt; :R: JNDER HO RHO , /N

|            | YIELD | TKN   | RECOVERY |
|------------|-------|-------|----------|
| CROP       | -0.26 | -0.87 | -0.74    |
|            | 0.07  | 0.01  | 0.01     |
|            | 48    | 48    | 48       |
| MANAGEMENT | -0.12 | 0.09  | 0.05     |
|            | 0.42  | 0.56  | 0.73     |
|            | 48    | 48    | 48       |
| YIELD      |       | 0.12  | 0.67     |
|            |       | 0.42  | 0.01     |
|            |       | 48    | 48       |
| TKN        |       |       | 0.77     |
|            |       |       | 0.01     |
|            |       |       | 48       |

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Table A1.2 - Analysis of variance by plant part.

LA-Acrustox SoilRoot

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 13584916.67 | 679245.83   | 3.92    | 0.0006 | 30.83 |
| Error      | 27 | 4681850.00  | 173401.85   |         |        |       |
| Cor. Total | 47 | 18266766.67 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 594629.17   | 1.71    | 0.1991 |
| Residue            | 1  | 350208.33   | 2.02    | 0.1667 |
| Residue*Rep        | 2  | 508454.17   | 0.89    | 0.4226 |
| Crop               | 1  | 1912008.33  | 11.03   | 0.0026 |
| Residue*Crop       | 1  | 3224033.33  | 18.59   | 0.0002 |
| Residue*Crop*Rep   | 4  | 3613433.33  | 5.21    | 0.0030 |
| Management         | 3  | 3274300.00  | 6.29    | 0.0022 |
| Residue*Management | 3  | 241691.67   | 0.46    | 0.7094 |
| Crop*Management    | 3  | 66158.33    | 0.13    | 0.9432 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 350208.33   | 2.27    | 0.2708 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 1912008.33  | 2.12    | 0.2194 |
| Residue*Crop | 1  | 3224033.33  | 3.57    | 0.1319 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 3.31        | 0.17        | 10.08   | 0.0001 | 12.89 |
| Error      | 27 | 0.44        | 0.02        |         |        |       |
| Cor. Total | 47 | 3.75        |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.01        | 0.37    | 0.6962 |
| Residue            | 1  | 0.19        | 11.30   | 0.0023 |
| Residue*Rep        | 2  | 0.06        | 1.81    | 0.1831 |
| Crop               | 1  | 2.40        | 145.21  | 0.0001 |
| Residue*Crop       | 1  | 0.02        | 1.17    | 0.2900 |
| Residue*Crop*Rep   | 4  | 0.08        | 1.14    | 0.3568 |
| Management         | 3  | 0.30        | 6.00    | 0.0028 |
| Residue*Management | 3  | 0.06        | 1.23    | 0.3186 |
| Crop*Management    | 3  | 0.20        | 4.11    | 0.0160 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.19        | 6.25    | 0.0296 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 2.40        | 127.71  | 0.0003 |
| Residue*Crop | 1  | 0.02        | 1.02    | 0.3702 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SJM | SQUARES | MEAN | SQUARE | F | VALUE | PR > F | C.V.  |
|------------|----|-----|---------|------|--------|---|-------|--------|-------|
| Model      | 20 |     | 73.92   |      | 3.70   |   | 13.16 | 0.0001 | 26.83 |
| Error      | 27 |     | 7.59    |      | 0.28   |   |       |        |       |
| Cor. Total | 47 |     | 81.51   |      |        |   |       |        |       |

| Source             | DF | TYPE III SS | F      | VALUE | PR > F |
|--------------------|----|-------------|--------|-------|--------|
| Rep                | 2  | 1.92        | 3.42   |       | 0.0476 |
| Residue            | 1  | 5.52        | 19.65  |       | 0.0001 |
| Residue*Rep        | 2  | 0.31        | 0.56   |       | 0.5783 |
| Crop               | 1  | 43.44       | 154.60 |       | 0.0001 |
| Residue*Crop       | 1  | 14.86       | 52.88  |       | 0.0001 |
| Residue*Crop*Rep   | 4  | 5.43        | 4.83   |       | 0.0045 |
| Management         | 3  | 2.22        | 2.64   |       | 0.0701 |
| Residue*Management | 3  | 0.06        | 0.07   |       | 0.9754 |
| Crop*Management    | 3  | 0.17        | 0.20   |       | 0.8971 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F     | VALUE | PR > F |
|---------|----|-------------|-------|-------|--------|
| Residue | 1  | 5.52        | 35.15 |       | 0.0273 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F     | VALUE | PR > F |
|--------------|----|-------------|-------|-------|--------|
| Crop         | 1  | 43.44       | 32.01 |       | 0.0048 |
| Residue*Crop | 1  | 14.86       | 10.95 |       | 0.0297 |

Table A1.2-continued.Top

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 77352141.67 | 3867607.08  | 9.52    | 0.0001 | 19.20 |
| Error      | 27 | 10973625.00 | 406430.56   |         |        |       |
| Cor. Total | 47 | 88325766.67 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 1467754.17  | 1.81    | 0.1837 |
| Residue            | 1  | 11524800.00 | 28.36   | 0.0001 |
| Residue*Rep        | 2  | 186637.50   | 0.23    | 0.7964 |
| Crop               | 1  | 23829008.33 | 58.63   | 0.0001 |
| Residue*Crop       | 1  | 18575408.33 | 45.70   | 0.0001 |
| Residue*Crop*Rep   | 4  | 3933358.33  | 2.42    | 0.0730 |
| Management         | 3  | 8978916.67  | 7.36    | 0.0009 |
| Residue*Management | 3  | 285116.67   | 0.23    | 0.6720 |
| Crop*Management    | 3  | 8571141.67  | 7.03    | 0.0012 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 11524800.00 | 123.50  | 0.0080 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 23829008.33 | 24.23   | 0.0079 |
| Residue*Crop | 1  | 18575408.33 | 18.89   | 0.0122 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 11.51       | 0.58        | 26.97   | 0.0001 | 16.88 |
| Error      | 27 | 0.58        | 0.02        |         |        |       |
| Cor. Total | 47 | 12.09       |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.05        | 1.19    | 0.3205 |
| Residue            | 1  | 0.19        | 8.98    | 0.0058 |
| Residue*Rep        | 2  | 0.06        | 1.29    | 0.2910 |
| Crop               | 1  | 10.94       | 512.43  | 0.0001 |
| Residue*Crop       | 1  | 0.05        | 2.18    | 0.1517 |
| Residue*Crop*Rep   | 4  | 0.11        | 1.34    | 0.2814 |
| Management         | 3  | 0.02        | 0.35    | 0.7921 |
| Residue*Management | 3  | 0.08        | 1.23    | 0.3170 |
| Crop*Management    | 3  | 0.02        | 0.24    | 0.8676 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.19        | 6.95    | 0.1168 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 10.94       | 382.95  | 0.0001 |
| Residue*Crop | 1  | 0.05        | 1.63    | 0.2712 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | J.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 1098.20     | 54.91       | 39.01   | 0.0001 | 24.16 |
| Error      | 27 | 38.01       | 1.41        |         |        |       |
| Cor. Total | 47 |             |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 4.31        | 1.53    | 0.2344 |
| Residue            | 1  | 151.71      | 107.77  | 0.0001 |
| Residue*Rep        | 2  | 1.81        | 0.64    | 0.5342 |
| Crop               | 1  | 678.28      | 481.83  | 0.0001 |
| Residue*Crop       | 1  | 162.94      | 113.75  | 0.0001 |
| Residue*Crop*Rep   | 4  | 7.50        | 1.33    | 0.2833 |
| Management         | 3  | 38.84       | 9.20    | 0.0002 |
| Residue*Management | 3  | 11.81       | 2.80    | 0.0592 |
| Crop*Management    | 3  | 41.00       | 9.71    | 0.0002 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 151.71      | 167.94  | 0.0059 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 678.28      | 361.57  | 0.0001 |
| Residue*Crop | 1  | 162.94      | 86.86   | 0.0007 |

Table A1.2-continued.Grain

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 24224808.33 | 1211240.42  | 10.28   | 0.0001 | 19.92 |
| Error      | 27 | 3180583.33  | 117799.38   |         |        |       |
| Cor. Total | 47 | 27405391.67 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 472879.17   | 2.01    | 0.1539 |
| Residue            | 1  | 4236408.33  | 35.96   | 0.0001 |
| Residue*Rep        | 2  | 776879.17   | 3.30    | 0.0523 |
| Crop               | 1  | 4813333.33  | 40.86   | 0.0001 |
| Residue*Crop       | 1  | 10230533.33 | 86.85   | 0.0001 |
| Residue*Crop*Rep   | 4  | 1089158.33  | 2.31    | 0.0834 |
| Management         | 3  | 1920891.67  | 5.44    | 0.0047 |
| Residue*Management | 3  | 260625.00   | 0.74    | 0.5589 |
| Crop*Management    | 3  | 424100.00   | 1.20    | 0.3286 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 4236408.33  | 10.91   | 0.0807 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 4813333.33  | 17.68   | 0.0136 |
| Residue*Crop | 1  | 10230533.33 | 37.57   | 0.036  |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 20 | 3.68        | 0.18        | 13.50   | 0.0001 | 7.55 |
| Error      | 27 | 0.37        | 0.01        |         |        |      |
| Cor. Total | 47 | 4.05        |             |         |        |      |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.09        | 3.30    | 0.0324 |
| Residue            | 1  | 0.004       | 0.30    | 0.5882 |
| Residue*Rep        | 2  | 0.04        | 1.57    | 0.2256 |
| Crop               | 1  | 3.21        | 235.02  | 0.0001 |
| Residue*Crop       | 1  | 0.09        | 6.95    | 0.0137 |
| Residue*Crop*Rep   | 4  | 0.06        | 1.11    | 0.3737 |
| Management         | 3  | 0.03        | 0.82    | 0.4945 |
| Residue*Management | 3  | 0.09        | 2.15    | 0.1171 |
| Crop*Management    | 3  | 0.06        | 1.57    | 0.2207 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.004       | 0.19    | 0.7049 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 3.21        | 212.39  | 0.0001 |
| Residue*Crop | 1  | 0.09        | 6.28    | 0.0564 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.v.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 189.59      | 9.48        | 10.99   | 0.0001 | 25.97 |
| Error      | 27 | 23.30       | 0.86        |         |        |       |
| Cor. Total | 47 | 212.88      |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 2.57        | 1.49    |        |
| Residue            | 1  | 44.26       | 51.50   |        |
| Residue*Rep        | 2  | 3.75        | 2.18    |        |
| Crop               | 1  | 10.74       | 12.45   |        |
| Residue*Crop       | 1  | 100.62      | 116.61  |        |
| Residue*Crop*Rep   | 4  | 5.22        | 1.51    |        |
| Management         | 3  | 13.27       | 5.13    |        |
| Residue*Management | 3  | 3.95        | 1.53    |        |
| Crop*Management    | 3  | 5.20        | 2.01    |        |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 44.26       | 23.58   | 0.0399 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 10.74       | 8.24    | 0.0455 |
| Residue*Crop | 1  | 100.62      | 77.16   | 0.0009 |

Table A1.2-continued.LE-Haplustox SoilRoot

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 7280075.00  | 280002.88   | 4.73    | 0.0001 | 22.38 |
| Error      | 45 | 2662290.28  | 59162.01    |         |        |       |
| Cor. Total | 71 | 9942365.28  |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 87244.44    | 0.74    | 0.4841 |
| Residue            | 1  | 787512.50   | 13.31   | 0.0007 |
| Residue*Rep        | 2  | 157033.33   | 1.33    | 0.2754 |
| Crop               | 1  | 1493568.06  | 25.25   | 0.0001 |
| Residue*Crop       | 1  | 1314901.39  | 22.23   | 0.0001 |
| Residue*Crop*Rep   | 4  | 383722.22   | 1.62    | 0.1853 |
| Management         | 5  | 2675490.28  | 9.04    | 0.0001 |
| Residue*Management | 5  | 191545.83   | 0.65    | 0.6648 |
| Crop*Management    | 5  | 189056.94   | 0.64    | 0.6710 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 787512.50   | 10.03   | 0.0869 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 1493568.06  | 15.57   | 0.0169 |
| Residue*Crop | 1  | 1314901.39  | 13.71   | 0.0208 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 5.90        | 0.23        | 15.69   | 0.0001 | 11.63 |
| Error      | 45 | 0.65        | 0.01        |         |        |       |
| Cor. Total | 71 | 6.55        |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.06        | 1.95    | 0.1544 |
| Residue            | 1  | 0.05        | 3.77    | 0.0584 |
| Residue*Rep        | 2  | 0.03        | 0.94    | 0.3990 |
| Crop               | 1  | 5.18        | 358.31  | 0.0001 |
| Residue*Crop       | 1  | 0.01        | 0.64    | 0.4267 |
| Residue*Crop*Rep   | 4  | 0.01        | 0.19    | 0.9410 |
| Management         | 5  | 0.37        | 5.11    | 0.0008 |
| Residue*Management | 5  | 0.06        | 0.85    | 0.5189 |
| Crop*Management    | 5  | 0.13        | 1.75    | 0.1424 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.05        | 4.02    | 0.1828 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 5.18        | 1850.49 | 0.0001 |
| Residue*Crop | 1  | 0.01        | 3.34    | 0.1416 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 64.01       | 2.46        | 13.17   | 0.0001 | 26.41 |
| Error      | 45 | 8.41        | 0.19        |         |        |       |
| Cor. Total | 71 | 72.42       |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.41        | 1.09    | 0.3461 |
| Residue            | 1  | 4.48        | 23.95   | 0.0001 |
| Residue*Rep        | 2  | 0.58        | 1.55    | 0.2233 |
| Crop               | 1  | 48.91       | 261.72  | 0.0001 |
| Residue*Crop       | 1  | 6.27        | 33.57   | 0.0001 |
| Residue*Crop*Rep   | 4  | 0.94        | 1.26    | 0.3003 |
| Management         | 5  | 1.18        | 1.26    | 0.2984 |
| Residue*Management | 5  | 0.59        | 0.63    | 0.6775 |
| Crop*Management    | 5  | 0.66        | 0.71    | 0.6189 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 4.48        | 15.45   | 0.0591 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 48.91       | 207.95  | 0.0001 |
| Residue*Crop | 1  | 6.27        | 26.67   | 0.0067 |

Table A1.2-continued.Top

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 26 | 63713294.44 | 2450511.32  | 22.59   | 0.0001 | 9.75 |
| Error      | 45 | 4881083.53  | 108468.52   |         |        |      |
| Cor. Total | 71 | 68594377.78 |             |         |        |      |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 220452.78   | 1.02    | 0.3701 |
| Residue            | 1  | 19364938.89 | 178.53  | 0.0001 |
| Residue*Rep        | 2  | 7186.11     | 0.03    | 0.9674 |
| Crop               | 1  | 21233472.22 | 195.76  | 0.0001 |
| Residue*Crop       | 1  | 15980088.89 | 147.32  | 0.0001 |
| Residue*Crop*Rep   | 4  | 1692305.56  | 3.90    | 0.0084 |
| Management         | 5  | 3957627.78  | 7.30    | 0.0001 |
| Residue*Management | 5  | 480344.44   | 0.89    | 0.4986 |
| Crop*Management    | 5  | 776877.78   | 1.43    | 0.2311 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 19364938.89 | 5389.55 | 0.0002 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 21233472.22 | 50.19   | 0.0021 |
| Residue*Crop | 1  | 15980088.89 | 37.77   | 0.0036 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 9.21        | 0.35        | 23.01   | 0.0001 | 16.72 |
| Error      | 45 | 0.69        | 0.02        |         |        |       |
| Cor. Total | 71 | 9.90        |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.03        | 1.05    | 0.3589 |
| Residue            | 1  | 0.12        | 8.02    | 0.0069 |
| Residue*Rep        | 2  | 0.03        | 0.95    | 0.3949 |
| Crop               | 1  | 8.22        | 534.05  | 0.0001 |
| Residue*Crop       | 1  | 0.01        | 0.64    | 0.4297 |
| Residue*Crop*Rep   | 4  | 0.04        | 0.66    | 0.6231 |
| Management         | 5  | 0.42        | 5.44    | 0.0005 |
| Residue*Management | 5  | 0.04        | 0.57    | 0.7234 |
| Crop*Management    | 5  | 0.29        | 3.77    | 0.0062 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | .12         | 8.46    | 0.1007 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 8.22        | 809.32  | 0.0001 |
| Residue*Crop | 1  | 0.01        | 0.96    | 0.3821 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 796.22      | 30.70       | 30.14   | 0.0001 | 25.09 |
| Error      | 45 | 45.83       | 1.02        |         |        |       |
| Cor. Total | 71 | 844.05      |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 2.27        | 1.12    | 0.3365 |
| Residue            | 1  | 120.69      | 118.51  | 0.0001 |
| Residue*Rep        | 2  | 1.03        | 0.50    | 0.6070 |
| Crop               | 1  | 539.08      | 529.32  | 0.0001 |
| Residue*Crop       | 1  | 117.21      | 115.09  | 0.0001 |
| Residue*Crop*Rep   | 4  | 1.17        | 0.42    | 0.7938 |
| Management         | 5  | 7.53        | 1.48    | 0.2157 |
| Residue*Management | 5  | 2.51        | 0.49    | 0.7796 |
| Crop*Management    | 5  | 6.19        | 1.21    | 0.3178 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 120.69      | 234.77  | 0.0042 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 539.08      | 1262.11 | 0.0001 |
| Residue*Crop | 1  | 117.21      | 274.42  | 0.0001 |

Table A1.2-continued.Grain

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 52350294.44 | 2013472.86  | 12.44   | 0.0001 | 19.37 |
| Error      | 45 | 7283705.56  | 161860.12   |         |        |       |
| Cor. Total | 71 | 59634000.00 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 62308.33    | 0.19    | 0.8256 |
| Residue            | 1  | 16188050.00 | 100.01  | 0.0001 |
| Residue*Rep        | 2  | 54658.33    | 0.17    | 0.8452 |
| Crop               | 1  | 38272.22    | 0.24    | 0.6291 |
| Residue*Crop       | 1  | 25680555.56 | 158.66  | 0.0001 |
| Residue*Crop*Rep   | 4  | 290588.89   | 0.45    | 0.7727 |
| Management         | 5  | 7679850.00  | 9.49    | 0.0001 |
| Residue*Management | 5  | 1358966.67  | 1.68    | 0.1591 |
| Crop*Management    | 5  | 997044.44   | 1.23    | 0.3100 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 16188050.00 | 592.34  | 0.0017 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 38272.22    | 0.53    | 0.5081 |
| Residue*Crop | 1  | 25680555.56 | 353.50  | 0.0001 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 6.81        | 0.26        | 5.01    | 0.0001 | 14.90 |
| Error      | 45 | 2.35        | 0.05        |         |        |       |
| Cor. Total | 71 | 9.16        |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.09        | 0.90    | 0.4146 |
| Residue            | 1  | 0.44        | 8.51    | 0.0055 |
| Residue*Rep        | 2  | 0.05        | 0.44    | 0.6492 |
| Crop               | 1  | 5.03        | 96.13   | 0.0001 |
| Residue*Crop       | 1  | 0.002       | 0.03    | 0.8564 |
| Residue*Crop*Rep   | 4  | 0.14        | 0.68    | 0.6082 |
| Management         | 5  | 0.50        | 1.92    | 0.1100 |
| Residue*Management | 5  | 0.49        | 1.86    | 0.1210 |
| Crop*Management    | 5  | 0.06        | 0.24    | 0.9406 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.44        | 19.51   | 0.0476 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 5.03        | 141.00  | 0.0003 |
| Residue*Crop | 1  | 0.002       | 0.05    | 0.8363 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 26 | 722.70      | 27.80       | 22.10   | 0.0001 | 25.03 |
| Error      | 42 | 52.83       | 1.26        |         |        |       |
| Cor. Total | 68 | 775.54      |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 1.69        | 0.67    | 0.5171 |
| Residue            | 1  | 168.61      | 134.03  | 0.0001 |
| Residue*Rep        | 2  | 0.20        | 0.08    | 0.9254 |
| Crop               | 1  | 133.74      | 106.31  | 0.0001 |
| Residue*Crop       | 1  | 259.16      | 206.01  | 0.0001 |
| Residue*Crop*Rep   | 4  | 4.66        | 0.93    | 0.4584 |
| Management         | 5  | 21.38       | 3.40    | 0.0114 |
| Residue*Management | 5  | 23.50       | 3.74    | 0.0069 |
| Crop*Management    | 5  | 4.34        | 0.69    | 0.6333 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 168.61      | 1725.31 | 0.0006 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 133.74      | 114.89  | 0.0004 |
| Residue*Crop | 1  | 259.16      | 222.63  | 0.0001 |

Table A1.2-continued.Virgin SoilsRoot

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 17174103.75 | 858705.19   | 4.93    | 0.0001 | 34.01 |
| Error      | 27 | 4707085.73  | 174336.54   |         |        |       |
| Cor. Total | 47 | 21881190.48 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 180049.54   | 0.52    | 0.6024 |
| Residue            | 1  | 876691.02   | 5.03    | 0.0333 |
| Residue*Rep        | 2  | 14554.54    | 0.04    | 0.9592 |
| Crop               | 1  | 894621.02   | 5.13    | 0.0317 |
| Residue*Crop       | 1  | 3845970.19  | 22.06   | 0.0001 |
| Residue*Crop*Rep   | 4  | 1342652.42  | 1.93    | 0.1350 |
| Management         | 3  | 9637202.23  | 18.43   | 0.0001 |
| Residue*Management | 3  | 45469.73    | 0.09    | 0.0966 |
| Crop*Management    | 3  | 336893.06   | 0.64    | 0.5934 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 876691.02   | 120.47  | 0.0082 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 894621.02   | 2.67    | 0.1779 |
| Residue*Crop | 1  | 3845970.19  | 11.46   | 0.0277 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 3.68        | 0.18        | 4.59    | 0.0002 | 18.46 |
| Error      | 27 | 1.08        | 0.04        |         |        |       |
| Cor. Total | 47 | 4.76        |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.07        | 0.85    | 0.4367 |
| Residue            | 1  | 0.29        | 7.28    | 0.0119 |
| Residue*Rep        | 2  | 0.09        | 1.16    | 0.3280 |
| Crop               | 1  | 1.54        | 38.52   | 0.0001 |
| Residue*Crop       | 1  | 0.004       | 0.09    | 0.7662 |
| Residue*Crop*Rep   | 4  | 0.11        | 0.70    | 0.5989 |
| Management         | 3  | 1.30        | 10.82   | 0.0001 |
| Residue*Management | 3  | 1.23        | 1.05    | 0.3947 |
| Crop*Management    | 3  | 0.14        | 1.18    | 0.3346 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.29        | 6.27    | 0.0293 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 1.54        | 55.05   | 0.0018 |
| Residue*Crop | 1  | 0.004       | 0.13    | 0.7377 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 61.27       | 3.06        | 6.27    | 0.0001 | 36.39 |
| Error      | 27 | 13.19       | 0.49        |         |        |       |
| Cor. Total | 47 | 74.46       |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.09        | 0.09    | 0.9133 |
| Residue            | 1  | 6.78        | 13.88   | 0.0009 |
| Residue*Rep        | 2  | 0.15        | 0.15    | 0.8622 |
| Crop               | 1  | 25.21       | 51.60   | 0.0001 |
| Residue*Crop       | 1  | 15.15       | 31.02   | 0.0001 |
| Residue*Crop*Rep   | 4  | 3.53        | 1.80    | 0.1570 |
| Management         | 3  | 7.64        | 5.21    | 0.0057 |
| Residue*Management | 3  | 1.31        | 0.90    | 0.4563 |
| Crop*Management    | 3  | 1.41        | 0.96    | 0.4260 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 6.78        | 93.12   | 0.0106 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 25.21       | 28.59   | 0.0059 |
| Residue*Crop | 1  | 15.16       | 17.19   | 0.0143 |

Table A1.2-continued.Top

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 52638633.33 | 2631931.67  | 6.73    | 0.0001 | 22.86 |
| Error      | 27 | 10552966.67 | 390850.62   |         |        |       |
| Cor. Total | 47 | 63191600.00 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 418212.50   | 0.54    | 0.5917 |
| Residue            | 1  | 9257633.33  | 23.69   | 0.0001 |
| Residue*Rep        | 2  | 78804.17    | 0.10    | 0.9044 |
| Crop               | 1  | 4368133.33  | 11.18   | 0.0024 |
| Residue*Crop       | 1  | 11097633.33 | 28.59   | 0.0001 |
| Residue*Crop*Rep   | 4  | 632733.33   | 0.40    | 0.8036 |
| Management         | 3  | 20639450.00 | 17.60   | 0.0001 |
| Residue*Management | 3  | 148616.67   | 0.13    | 0.9454 |
| Crop*Management    | 3  | 5997416.67  | 5.11    | 0.0062 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 9257633.33  | 234.95  | 0.0042 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 4368133.33  | 27.61   | 0.0063 |
| Residue*Crop | 1  | 11097633.33 | 70.16   | 0.0011 |

Table A1.2-continued.

Dependent Variable: TKN

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 10.30       | 0.52        | 17.52   | 0.0001 | 18.66 |
| Error      | 27 | 0.79        | 0.03        |         |        |       |
| Cor. Total | 47 | 11.10       |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 0.04        | 0.67    | 0.5206 |
| Residue            | 1  | 0.39        | 15.24   | 0.0012 |
| Residue*Rep        | 2  | 0.06        | 1.10    | 0.3484 |
| Crop               | 1  | 8.44        | 287.11  | 0.0001 |
| Residue*Crop       | 1  | 0.09        | 2.93    | 0.0982 |
| Residue*Crop*Rep   | 4  | 0.07        | 0.64    | 0.6413 |
| Management         | 3  | 0.45        | 5.07    | 0.0065 |
| Residue*Management | 3  | 0.30        | 3.37    | 0.0330 |
| Crop*Management    | 3  | 0.46        | 5.26    | 0.0055 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 0.39        | 12.07   | 0.0738 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 8.44        | 451.51  | 0.0001 |
| Residue*Crop | 1  | 0.09        | 4.61    | 0.0982 |

Table A1.2-continued.

Dependent Variable: Recovery

| Source     | DF | SUM    | SQUARES | MEAN  | SQUARE | F      | VALUE | PR > F | C.V. |
|------------|----|--------|---------|-------|--------|--------|-------|--------|------|
| Model      | 20 | 485.25 |         | 24.26 | 18.63  | 0.0001 | 29.02 |        |      |
| Error      | 27 | 35.17  |         | 1.30  |        |        |       |        |      |
| Cor. Total | 47 | 520.42 |         |       |        |        |       |        |      |

| Source             | DF | TYPE III SS | F      | VALUE  | PR > F |
|--------------------|----|-------------|--------|--------|--------|
| Rep                | 2  | 1.43        | 0.55   | 0.5642 |        |
| Residue            | 1  | 85.83       | 65.89  | 0.0001 |        |
| Residue*Rep        | 2  | 2.50        | 0.96   | 0.3957 |        |
| Crop               | 1  | 283.61      | 217.71 | 0.0001 |        |
| Residue*Crop       | 1  | 89.28       | 68.54  | 0.0001 |        |
| Residue*Crop*Rep   | 4  | 3.91        | 0.75   | 0.5670 |        |
| Management         | 3  | 5.95        | 1.52   | 0.2315 |        |
| Residue*Management | 3  | 2.00        | 0.51   | 0.6769 |        |
| Crop*Management    | 3  | 10.74       | 2.75   | 0.0622 |        |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F     | VALUE  | PR > F |
|---------|----|-------------|-------|--------|--------|
| Residue | 1  | 85.83       | 68.65 | 0.0143 |        |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F      | VALUE  | PR > F |
|--------------|----|-------------|--------|--------|--------|
| Crop         | 1  | 283.61      | 290.50 | 0.0001 |        |
| Residue*Crop | 1  | 89.28       | 91.45  | 0.0007 |        |

Table A1.2-continued.Grain

Dependent Variable: Yield

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 45667160.58 | 2283358.03  | 10.33   | 0.0001 | 33.40 |
| Error      | 27 | 5967803.90  | 221029.77   |         |        |       |
| Cor. Total | 47 | 51634964.48 |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 165165.29   | 0.37    | 0.6917 |
| Residue            | 1  | 5176503.52  | 23.42   | 0.0001 |
| Residue*Rep        | 2  | 711248.04   | 1.61    | 0.2187 |
| Crop               | 1  | 1795293.52  | 8.12    | 0.0083 |
| Residue*Crop       | 1  | 5519598.52  | 24.97   | 0.0001 |
| Residue*Crop*Rep   | 4  | 412893.33   | 0.47    | 0.7594 |
| Management         | 3  | 26636307.23 | 40.17   | 0.0001 |
| Residue*Management | 3  | 1425595.56  | 2.15    | 0.1172 |
| Crop*Management    | 3  | 3824555.56  | 5.77    | 0.0035 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 5176503.52  | 14.56   | 0.0623 |

Test of hypothesis using the TYPE III MS for

Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 1795293.52  | 17.39   | 0.0140 |
| Residue*Crop | 1  | 5519598.52  | 53.47   | 0.0019 |

Table A1.2-continued.

Dependent Variable: Y.M

| Source     | DF | SJM | SQ | RES  | MEAN | SQUARE | F | VALUE | PR > F | C.V. |
|------------|----|-----|----|------|------|--------|---|-------|--------|------|
| Model      | 20 |     |    | 5.07 |      | 0.15   |   | 8.45  | 0.0001 | 8.70 |
| Error      | 27 |     |    | 5.49 |      | 0.02   |   |       |        |      |
| Cor. Total | 47 |     |    | 5.57 |      |        |   |       |        |      |

| Source             | DF | TYPE III | SS   | F | VALUE  | PR > F |
|--------------------|----|----------|------|---|--------|--------|
| Rep                | 2  |          | 0.02 |   | 0.47   | 0.6294 |
| Residue            | 1  |          | 0.01 |   | 0.52   | 0.4768 |
| Residue*Rep        | 2  |          | 0.05 |   | 1.41   | 0.2615 |
| Crop               | 1  |          | 2.52 |   | 138.74 | 0.0001 |
| Residue*Crop       | 1  |          | 0.08 |   | 4.15   | 0.0515 |
| Residue*Crop*Rep   | 4  |          | 0.11 |   | 1.54   | 0.2199 |
| Management         | 3  |          | 0.09 |   | 1.60   | 0.2116 |
| Residue*Management | 3  |          | 0.03 |   | 0.57   | 0.6410 |
| Crop*Management    | 3  |          | 0.17 |   | 3.06   | 0.0453 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE II | SS   | F | VALUE | PR > F |
|---------|----|---------|------|---|-------|--------|
| Residue | 1  |         | 0.01 |   | 0.37  | 0.6052 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III | SS   | F | VALUE | PR > F |
|--------------|----|----------|------|---|-------|--------|
| Crop         | 1  |          | 2.52 |   | 90.31 | 0.0007 |
| Residue*Crop | 1  |          | 0.08 |   | 2.70  | 0.1755 |

Table A1.2-continued.

Dependent Variables: Recovery

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V.  |
|------------|----|-------------|-------------|---------|--------|-------|
| Model      | 20 | 249.25      | 12.46       | 8.10    | 0.0001 | 42.02 |
| Error      | 24 | 36.94       | 1.54        |         |        |       |
| Cor. Total | 44 | 286.19      |             |         |        |       |

| Source             | DF | TYPE III SS | F VALUE | PR > F |
|--------------------|----|-------------|---------|--------|
| Rep                | 2  | 1.48        | 0.48    | 0.6241 |
| Residue            | 1  | 52.17       | 33.90   | 0.0001 |
| Residue*Rep        | 2  | 3.25        | 1.06    | 0.3634 |
| Crop               | 1  | 0.91        | 0.59    | 0.4504 |
| Residue*Crop       | 1  | 27.30       | 17.74   | 0.0003 |
| Residue*Crop*Rep   | 4  | 3.99        | 0.65    | 0.6335 |
| Management         | 3  | 69.37       | 15.02   | 0.0001 |
| Residue*Management | 3  | 20.25       | 4.39    | 0.0135 |
| Crop*Management    | 3  | 18.05       | 3.91    | 0.0209 |

Test of hypothesis using the TYPE III MS for Residue\*Rep as an error term

| Source  | DF | TYPE III SS | F VALUE | PR > F |
|---------|----|-------------|---------|--------|
| Residue | 1  | 52.17       | 32.10   | 0.0298 |

Test of hypothesis using the TYPE III MS for Residue\*Crop\*Rep as an error term

| Source       | DF | TYPE III SS | F VALUE | PR > F |
|--------------|----|-------------|---------|--------|
| Crop         | 1  | 0.91        | 0.91    | 0.3946 |
| Residue*Crop | 1  | 27.30       | 27.35   | 0.0064 |

Table A1.3 - Analysis of atom %  $^{15}\text{N}$  by residue type.LA-Acrustox SoilGrass residueDependent Variable: Atom %  $^{15}\text{N}$ 

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 14 | 0.04304725  | 0.00307480  | 80.15   | 0.0001 | 1.09 |
| Error      | 57 | 0.00218663  | 0.00003836  |         |        |      |
| Cor. Total | 71 | 0.04523388  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.00355075  | 46.28   | 0.0001 |
| Crop                  | 1  | 0.02343613  | 610.92  | 0.0001 |
| Crop*Part plant       | 2  | 0.00449275  | 58.56   | 0.0001 |
| Management            | 3  | 0.00893537  | 77.64   | 0.0001 |
| Part plant*Management | 6  | 0.00263225  | 11.44   | 0.0001 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.00355075  | 0.79    | 0.5586 |
| Crop       | 1  | 0.02343613  | 10.43   | 0.0840 |

Legume residueDependent Variable: Atom %  $^{15}\text{N}$ 

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 14 | 1.14284775  | 0.08163198  | 282.39  | 0.0001 | 1.86 |
| Error      | 57 | 0.01647713  | 0.00028907  |         |        |      |
| Cor. Total | 71 | 1.15932488  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.00689925  | 11.93   | 0.0001 |
| Crop                  | 1  | 1.12425013  | 3889.16 | 0.0001 |
| Crop*Part plant       | 2  | 0.00215925  | 3.70    | 0.0308 |
| Management            | 3  | 0.00616038  | 7.10    | 0.0004 |
| Part plant*Management | 6  | 0.00339875  | 1.96    | 0.0867 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.00689925  | 3.23    | 0.2367 |
| Crop       | 1  | 1.12425013  | 1051.07 | 0.0010 |

Table A1.3-continued.

LE-Haplustox SoilGrass residueDependent Variable: Atom % <sup>15</sup>N

| Source     | DF  | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|-----|-------------|-------------|---------|--------|------|
| Model      | 20  | 0.06557417  | 0.00327871  | 33.06   | 0.0001 | 1.64 |
| Error      | 87  | 0.00862750  | 0.00009717  |         |        |      |
| Cor. Total | 107 | 0.07420167  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.00696517  | 35.12   | 0.0001 |
| Crop                  | 1  | 0.02430000  | 245.04  | 0.0001 |
| Crop*Part plant       | 2  | 0.00926150  | 46.70   | 0.0001 |
| Management            | 5  | 0.02326267  | 46.96   | 0.0001 |
| Part plant*Management | 10 | 0.00176483  | 1.78    | 0.0762 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.00696517  | 0.75    | 0.5706 |
| Crop       | 1  | 0.02430000  | 5.25    | 0.1491 |

Legume residueDependent Variable: Atom % <sup>15</sup>N

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 14 | 1.69971381  | 0.08498569  | 226.81  | 0.0001 | 2.12 |
| Error      | 57 | 0.03147425  | 0.00037469  |         |        |      |
| Cor. Total | 71 | 1.73118806  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.01280134  | 17.08   | 0.0001 |
| Crop                  | 1  | 1.53527258  | 4097.41 | 0.0001 |
| Crop*Part plant       | 2  | 0.01213640  | 16.20   | 0.0001 |
| Management            | 5  | 0.12456231  | 66.49   | 0.0001 |
| Part plant*Management | 10 | 0.01036303  | 2.77    | 0.0053 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.01280134  | 1.05    | 0.4867 |
| Crop       | 1  | 1.53527258  | 253.00  | 0.0039 |

Table A1.3-continued.Virgin SoilsGrass residueDependent Variable: Atom % <sup>15</sup>N

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 14 | 0.23335375  | 0.01666812  | 52.17   | 0.0001 | 2.80 |
| Error      | 54 | 0.01821113  | 0.00031949  |         |        |      |
| Cor. Total | 68 | 0.25156488  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.01129525  | 17.68   | 0.0001 |
| Crop                  | 1  | 0.01193513  | 37.36   | 0.0001 |
| Crop*Part plant       | 2  | 0.01118325  | 17.50   | 0.0001 |
| Management            | 3  | 0.19503457  | 205.48  | 0.0001 |
| Part plant*Management | 6  | 0.00390575  | 2.04    | 0.0753 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.01129525  | 1.01    | 0.4975 |
| Crop       | 1  | 0.01193513  | 2.13    | 0.2815 |

Legume residueDependent Variable: Atom % <sup>15</sup>N

| Source     | DF | SUM SQUARES | MEAN SQUARE | F VALUE | PR > F | C.V. |
|------------|----|-------------|-------------|---------|--------|------|
| Model      | 14 | 0.88684240  | 0.06334589  | 171.43  | 0.0001 | 2.02 |
| Error      | 54 | 0.01995325  | 0.00036950  |         |        |      |
| Cor. Total | 68 | 0.90679565  |             |         |        |      |

| Source                | DF | TYPE III SS | F VALUE | PR > F |
|-----------------------|----|-------------|---------|--------|
| Part plant            | 2  | 0.00803184  | 10.87   | 0.0001 |
| Crop                  | 1  | 0.55078805  | 1490.61 | 0.0001 |
| Crop*Part plant       | 2  | 0.00068211  | 0.92    | 0.4035 |
| Management            | 3  | 0.27903033  | 251.72  | 0.0001 |
| Part plant*Management | 6  | 0.00616972  | 2.78    | 0.0197 |

Test of hypothesis using the TYPE III MS for Crop\*Part as an error term

| Source     | DF | TYPE III SS | F VALUE | PR > F |
|------------|----|-------------|---------|--------|
| Part Plant | 2  | 0.00803184  | 11.77   | 0.0783 |
| Crop       | 1  | 0.55078805  | 1614.95 | 0.0006 |

Table A1.4 - Orthonogonal contrasts between fertility programs. Yield, TKN and %  $^{15}\text{N}$  recovery by plant part.LA-Acrustox Soil

| Contrast                     | Dependent Variable |        |                            |
|------------------------------|--------------------|--------|----------------------------|
|                              | Yield              | TKN    | % $^{15}\text{N}$ Recovery |
|                              | PR > F             |        |                            |
| G R 1 : virgin vs. AD2 & AD3 | 0.7510             | 0.0064 | 0.9916                     |
| G R 2 : virgin vs. AD2 & AD3 | 0.0531             | 0.9074 | 0.1957                     |
| L R 1 : virgin vs. AD2 & AD3 | 0.0100             | 0.0003 | 0.3125                     |
| L R 2 : virgin vs. AD2 & AD3 | 0.3203             | 0.5571 | 0.6922                     |
| G R 1 : AD1 vs. AD2 & AD3    | 0.2156             | 0.0307 | 0.5928                     |
| G R 2 : AD1 vs. AD2 & AD3    | 0.8704             | 0.9949 | 0.8119                     |
| L R 1 : AD1 vs. AD2 & AD3    | 0.1752             | 0.1101 | 0.5736                     |
| L R 2 : AD1 vs. AD2 & AD3    | 0.3982             | 0.7900 | 0.7070                     |
| G R 1 : AD2 vs. AD3          | 0.5416             | 0.3572 | 0.6438                     |
| G R 2 : AD2 vs. AD3          | 0.5985             | 0.8119 | 0.9486                     |
| L R 1 : AD2 vs. AD3          | 0.8726             | 0.4448 | 0.7537                     |
| L R 2 : AD2 vs. AD3          | 0.4924             | 0.4964 | 0.6812                     |
| G T 1 : virgin vs. AD2 & AD3 | 0.0001             | 0.3910 | 0.0031                     |
| G T 2 : virgin vs. AD2 & AD3 | 0.9332             | 0.6982 | 0.8259                     |
| L T 1 : virgin vs. AD2 & AD3 | 0.0001             | 0.6337 | 0.0001                     |
| L T 2 : virgin vs. AD2 & AD3 | 0.9403             | 0.9343 | 0.9235                     |
| G T 1 : AD1 vs. AD2 & AD3    | 0.0137             | 0.1443 | 0.3675                     |
| G T 2 : AD1 vs. AD2 & AD3    | 0.7410             | 0.6842 | 0.8061                     |
| L T 1 : AD1 vs. AD2 & AD3    | 0.9018             | 0.0749 | 0.0013                     |
| L T 2 : AD1 vs. AD2 & AD3    | 0.0531             | 0.6927 | 0.5377                     |
| G T 1 : AD2 vs. AD3          | 0.3221             | 0.1015 | 0.3244                     |
| G T 2 : AD2 vs. AD3          | 0.3891             | 0.9198 | 0.9430                     |
| L T 1 : AD2 vs. AD3          | 0.0386             | 0.7738 | 0.0073                     |
| L T 2 : AD2 vs. AD3          | 0.3333             | 0.7752 | 0.7051                     |
| G R 1 : virgin vs. AD2 & AD3 | 0.2934             | 0.9144 | 0.1430                     |
| G R 2 : virgin vs. AD2 & AD3 | 0.5669             | 0.8529 | 0.6182                     |
| L R 1 : virgin vs. AD2 & AD3 | 0.0259             | 0.0556 | 0.0001                     |
| L R 2 : virgin vs. AD2 & AD3 | 0.2238             | 0.6365 | 0.3325                     |
| G R 1 : AD1 vs. AD2 & AD3    | 0.6884             | 0.1436 | 0.8696                     |
| G R 2 : AD1 vs. AD2 & AD3    | 0.6594             | 0.9887 | 0.9818                     |
| L R 1 : AD1 vs. AD2 & AD3    | 0.8187             | 0.4630 | 0.1103                     |
| L R 2 : AD1 vs. AD2 & AD3    | 0.1894             | 0.0596 | 0.1384                     |
| G R 1 : AD2 vs. AD3          | 0.9939             | 0.7075 | 0.9051                     |
| G R 2 : AD2 vs. AD3          | 0.9756             | 0.6221 | 0.9929                     |
| L R 1 : AD2 vs. AD3          | 0.8907             | 0.4054 | 0.5139                     |
| L R 2 : AD2 vs. AD3          | 0.5266             | 0.8138 | 0.6189                     |

Table A1.4-continued.

LE-Haplustox Soil

| Contrast                     | Dependent Variable |        |                            |
|------------------------------|--------------------|--------|----------------------------|
|                              | Yield              | TKN    | % <sup>15</sup> N Recovery |
|                              | PR > F             |        |                            |
| G R 1 : 5 vs. 7              | 0.9518             | 0.4964 | 0.9859                     |
| G R 1 : 9 vs. 11             | 0.3779             | 0.1829 | 0.6367                     |
| G R 1 : 13 vs. 5, 7, 9, & 11 | 0.2390             | 0.3726 | 0.9441                     |
| G R 1 : 13 vs. 14            | 0.0242             | 0.7802 | 0.2813                     |
| G R 2 : 5 vs. 7              | 0.8182             | 0.5763 | 0.9544                     |
| G R 2 : 9 vs. 11             | 0.5139             | 0.7559 | 0.9095                     |
| G R 2 : 13 vs. 5, 7, 9, & 11 | 0.0051             | 0.8301 | 0.5064                     |
| G R 2 : 13 vs. 14            | 0.9043             | 0.3160 | 0.6268                     |
| L R 1 : 5 vs. 7              | 0.3586             | 0.8954 | 0.5050                     |
| L R 1 : 9 vs. 11             | 0.5536             | 0.0416 | 0.6357                     |
| L R 1 : 13 vs. 5, 7, 9, & 11 | 0.0059             | 0.0695 | 0.6126                     |
| L R 1 : 13 vs. 14            | 0.0412             | 0.7124 | 0.7648                     |
| L R 2 : 5 vs. 7              | 0.3910             | 0.2749 | 0.9407                     |
| L R 2 : 9 vs. 11             | 0.6633             | 0.6888 | 0.9974                     |
| L R 2 : 13 vs. 5, 7, 9, & 11 | 0.947              | 0.8000 | 0.7325                     |
| L R 2 : 13 vs. 14            | 0.2140             | 0.3964 | 0.7066                     |
| G T 1 : 5 vs. 7              | 0.0022             | 0.1110 | 0.9409                     |
| G T 1 : 9 vs. 11             | 0.7349             | 0.2414 | 0.7153                     |
| G T 1 : 13 vs. 5, 7, 9, & 11 | 0.2903             | 0.1732 | 0.2984                     |
| G T 1 : 13 vs. 14            | 0.0052             | 0.0024 | 0.0028                     |
| G T 2 : 5 vs. 7              | 0.3586             | 0.9201 | 0.9684                     |
| G T 2 : 9 vs. 11             | 0.1066             | 0.5581 | 0.8363                     |
| G T 2 : 13 vs. 5, 7, 9, & 11 | 0.4819             | 0.5357 | 0.9490                     |
| G T 2 : 13 vs. 14            | 0.3586             | 0.5824 | 0.9832                     |
| L T 1 : 5 vs. 7              | 0.0041             | 0.8659 | 0.0156                     |
| L T 1 : 9 vs. 11             | 0.5617             | 0.5581 | 0.1179                     |
| L T 1 : 13 vs. 5, 7, 9, & 11 | 0.6381             | 0.0118 | 0.0262                     |
| L T 1 : 13 vs. 14            | 0.6201             | 0.0059 | 0.0880                     |
| L T 2 : 5 vs. 7              | 0.2467             | 0.7570 | 0.7674                     |
| L T 2 : 9 vs. 11             | 0.9037             | 0.7925 | 0.9457                     |
| L T 2 : 13 vs. 5, 7, 9, & 11 | 0.0289             | 0.4679 | 0.6809                     |
| L T 2 : 13 vs. 14            | 0.1321             | 0.8342 | 0.9270                     |
| G G 1 : 5 vs. 7              | 0.0282             | 0.2035 | 0.1362                     |
| G G 1 : 9 vs. 11             | 0.0576             | 0.1705 | 0.1691                     |
| G G 1 : 13 vs. 5, 7, 9, & 11 | 0.0437             | 0.6455 | 0.1566                     |
| G G 1 : 13 vs. 14            | 0.0624             | 0.3445 | 0.1273                     |
| G G 2 : 5 vs. 7              | 0.9518             | 0.9893 | 0.9661                     |
| G G 2 : 9 vs. 11             | 0.0832             | 0.6615 | 0.2525                     |
| G G 2 : 13 vs. 5, 7, 9, & 11 | 0.0105             | 0.1519 | 0.3918                     |
| G G 2 : 13 vs. 14            | 0.0020             | 0.3160 | 0.2893                     |

Table A1.4-continued.

LE-Haplustox Soil - continued

| Contrast                     | Dependent Variable |        |                            |
|------------------------------|--------------------|--------|----------------------------|
|                              | Yield              | TKN    | % <sup>15</sup> N Recovery |
|                              | PR > F             |        |                            |
| L G 1 : 5 vs. 7              | 0.0195             | 0.0014 | 0.0001                     |
| L G 1 : 9 vs. 11             | 0.0624             | 0.3198 | 0.2457                     |
| L G 1 : 13 vs. 5, 7, 9, & 11 | 0.0018             | 0.5277 | 0.0742                     |
| L G 1 : 13 vs. 14            | 0.1146             | 0.6539 | 0.1074                     |
| L G 2 : 5 vs. 7              | 0.5218             | 0.0085 | 0.1010                     |
| L G 2 : 9 vs. 11             | 0.2720             | 0.7020 | 0.9930                     |
| L G 2 : 13 vs. 5, 7, 9, & 11 | 0.0001             | 0.4860 | 0.8437                     |
| L G 2 : 13 vs. 14            | 0.0001             | 0.1668 | No-est                     |

Table A1.4-continued.

Virgin Soils

| Contrast                     | Dependent Variable |        |                            |
|------------------------------|--------------------|--------|----------------------------|
|                              | Yield              | TKN    | % <sup>15</sup> N Recovery |
|                              | PR > F             |        |                            |
| G R 1 : LA vs. LE            | 0.6995             | 0.0125 | 0.9574                     |
| G R 1 : Dothan vs. Troup     | 0.2989             | 0.3341 | 0.5250                     |
| G R 1 : Oxisols vs. Ultisols | 0.0041             | 0.0142 | 0.1616                     |
| G R 2 : LA vs. LE            | 0.2936             | 0.8313 | 0.4142                     |
| G R 2 : Dothan vs. Troup     | 0.3141             | 0.4700 | 0.0165                     |
| G R 2 : Oxisols vs. Ultisols | 0.0021             | 0.0784 | 0.0016                     |
| L R 1 : LA vs. LE            | 0.1573             | 0.4029 | 0.2337                     |
| L R 1 : Dothan vs. Troup     | 0.0104             | 0.4692 | 0.5218                     |
| L R 1 : Oxisols vs. Ultisols | 0.0009             | 0.0001 | 0.0001                     |
| L R 2 : LA vs. LE            | 0.7388             | 0.5664 | 0.8783                     |
| L R 2 : Dothan vs. Troup     | 0.7789             | 0.0069 | 0.3073                     |
| L R 2 : Oxisols vs. Ultisols | 0.0146             | 0.0006 | 0.0010                     |
| G T 1 : LA vs. LE            | 0.0004             | 0.5427 | 0.1392                     |
| G T 1 : Dothan vs. Troup     | 0.0013             | 0.4675 | 0.5867                     |
| G T 1 : Oxisols vs. Ultisols | 0.0031             | 0.5585 | 0.0001                     |
| G T 2 : LA vs. LE            | 0.7322             | 0.5825 | 0.9915                     |
| G T 2 : Dothan vs. Troup     | 0.0309             | 0.7856 | 0.4573                     |
| G T 2 : Oxisols vs. Ultisols | 0.0042             | 0.2222 | 0.0001                     |
| L T 1 : LA vs. LE            | 0.0003             | 0.6029 | 0.0045                     |
| L T 1 : Dothan vs. Troup     | 0.0001             | 0.0001 | 0.6211                     |
| L T 1 : Oxisols vs. Ultisols | 0.0150             | 0.2144 | 0.0001                     |
| L T 2 : LA vs. LE            | 0.1269             | 0.7856 | 0.9289                     |
| L T 2 : Dothan vs. Troup     | 0.3955             | 0.8591 | 0.3054                     |
| L T 2 : Oxisols vs. Ultisols | 0.0001             | 0.0039 | 0.4537                     |
| G G 1 : LA vs. LE            | 0.0115             | 0.7301 | 0.0239                     |
| G G 1 : Dothan vs. Troup     | 0.2741             | 0.0089 | 0.4136                     |
| G G 1 : Oxisols vs. Ultisols | 0.0359             | 0.9062 | 0.9299                     |
| G G 2 : LA vs. LE            | 0.0847             | 0.5505 | 0.6141                     |
| G G 2 : Dothan vs. Troup     | 0.6609             | 0.3790 | 0.0001                     |
| G G 2 : Oxisols vs. Ultisols | 0.0001             | 0.7697 | 0.8298                     |
| L G 1 : LA vs. LE            | 0.0001             | 0.1495 | 0.0001                     |
| L G 1 : Dothan vs. Troup     | 0.0009             | 0.2974 | 0.0293                     |
| L G 1 : Oxisols vs. Ultisols | 0.0001             | 0.6208 | 0.0001                     |
| L G 2 : LA vs. LE            | 0.0011             | 0.5081 | 0.3542                     |
| L G 2 : Dothan vs. Troup     | 0.0360             | 0.8530 | No-est                     |
| L G 2 : Oxisols vs. Ultisols | 0.0001             | 0.9045 | No-est                     |

Table A1.5 - Orthogonal contrasts between fertility programs. %  $^{15}\text{N}$  recovery in sum of plant parts.

LA-Acrustox Soil

| Residue Crop       | Contrast            |                        |             |
|--------------------|---------------------|------------------------|-------------|
|                    | AD1 vs.<br>AD2, AD3 | Virgin vs.<br>AD2, AD3 | AD2 vs. AD3 |
| ----- PR > F ----- |                     |                        |             |
|                    |                     | Whole Plant            |             |
| Grass 1            | 0.3709              | 0.0284                 | 0.4495      |
| Grass 2            | 0.7342              | 0.4983                 | 0.9223      |
| Grass 1 + 2        | 0.2355              | 0.0035                 | 0.1196      |
| Legume 1           | 0.3173              | 0.0108                 | 0.5743      |
| Legume 2           | 0.0227              | 0.6017                 | 0.7494      |
| Legume 1 + 2       | 0.1167              | 0.0071                 | 0.5100      |
|                    |                     | Returnable Portion     |             |
| Grass 1            | 0.3935              | 0.0933                 | 0.3857      |
| Grass 2            | 0.5513              | 0.0864                 | 0.8655      |
| Grass 1 + 2        | 0.4245              | 0.2176                 | 0.1963      |
| Legume 1           | 0.3554              | 0.0134                 | 0.3075      |
| Legume 2           | 0.1171              | 0.4095                 | 0.2001      |
| Legume 1 + 2       | 0.2104              | 0.0161                 | 0.1996      |

Table A1.5-continued.

LE-Haplustox Soil

| Residue Crop       | Contrast   |             |              |                    |                    |
|--------------------|------------|-------------|--------------|--------------------|--------------------|
|                    | 5 vs.<br>7 | 9 vs.<br>11 | 13 vs.<br>14 | 13 vs.<br>5,6,9,11 | 14 vs.<br>5,7,9,11 |
| ----- PR > F ----- |            |             |              |                    |                    |
| Whole Plant        |            |             |              |                    |                    |
| Grass 1            | 0.0325     | 0.0428      | 0.0001       | 0.0023             | 0.0001             |
| Grass 2            | 0.9369     | 0.1426      | 0.0377       | 0.0360             | 0.5640             |
| Grass 1 + 2        | 0.0219     | 0.0015      | 0.0001       | 0.0001             | 0.0001             |
| Legume 1           | 0.5272     | 0.7393      | 0.8806       | 0.1043             | 0.1439             |
| Legume 2           | 0.3313     | 0.9502      | no-est       | 0.5082             | no-est             |
| Legume 1 + 2       | 0.3247     | 0.7852      | no-est       | 0.2914             | no-est             |
| Returnable Portion |            |             |              |                    |                    |
| Grass 1            | 0.8922     | 0.8737      | 0.0001       | 0.1192             | 0.0001             |
| Grass 2            | 0.8309     | 0.8376      | 0.2751       | 0.1264             | 0.8477             |
| Grass 1 + 2        | 0.8024     | 0.9844      | 0.0001       | 0.0281             | 0.0001             |
| Legume 1           | 0.2377     | 0.4301      | 0.4368       | 0.2936             | 0.9370             |
| Legume 2           | 0.6657     | 0.9334      | 0.5857       | 0.9351             | 0.4440             |
| Legume 1 + 2       | 0.1853     | 0.4413      | 0.3362       | 0.3007             | 0.8560             |

Table A1.5-continued.

Virgin Soils

| Residue Crop |       |  | Contrast                |           |                     |
|--------------|-------|--|-------------------------|-----------|---------------------|
|              |       |  | Oxisols vs.<br>Ultisols | LA vs. LE | Dothan vs.<br>Troup |
|              |       |  | PR > F                  |           |                     |
|              |       |  | Whole Plant             |           |                     |
| Grass        | 1     |  | 0.0078                  | 0.0410    | 0.1152              |
| Grass        | 2     |  | 0.0690                  | 0.7905    | 0.7514              |
| Grass        | 1 + 2 |  | 0.0001                  | 0.0143    | 0.0235              |
| Legume       | 1     |  | 0.0386                  | 0.0149    | 0.0324              |
| Legume       | 2     |  | no-est                  | 0.4254    | no-est              |
| Legume       | 1 + 2 |  | no-est                  | 0.5531    | no-est              |
|              |       |  | Returnable Portion      |           |                     |
| Grass        | 1     |  | 0.0356                  | 0.3281    | 0.2577              |
| Grass        | 2     |  | 0.5670                  | 0.2438    | 0.1031              |
| Grass        | 1 + 2 |  | 0.0168                  | 0.5589    | 0.0239              |
| Legume       | 1     |  | 0.7489                  | 0.4889    | 0.2144              |
| Legume       | 2     |  | 0.4486                  | 0.8441    | 0.9052              |
| Legume       | 1 + 2 |  | 0.9463                  | 0.5640    | 0.2098              |

APPENDIX 2  
STATISTICAL ANALYSIS FOR SOILS

Abbreviations

REC-SOIL: N left in soil, and glasshouse experiment  
REC-PLNT: N recovered by plants in two crops  
UNACC : N not accounted for (losses)  
TKN-INIT: soil TKN of original samples  
TKN-FIN : soil TKN, end glasshouse experiment  
CN-INIT : soil C:N ratio of original samples  
CN-FIN : soil C:N ratio, end glasshouse experiment  
DIFF-CN : (soil C:N ratio end glasshouse experiment) -  
          (soil C:N ratio original samples)  
DIFF-TKN: (soil TKN end glasshouse experiment) -  
          (soil TKN original samples)

Table A2.1 - Correlations for LA soil.

| CORRELATIONS WITH BOTH RESIDUES COMBINED |    |         |         |         |         |         |
|------------------------------------------|----|---------|---------|---------|---------|---------|
| VARIABLE                                 | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
| TKN-FIN                                  | 24 | 0.1065  | 0.0251  | 2.56    | 0.0574  | 0.1381  |
| CN-INIT                                  | 16 | 11.8229 | 1.0438  | 189.17  | 9.8952  | 12.9737 |
| CN-FIN                                   | 24 | 12.5673 | 2.7645  | 301.61  | 10.7045 | 24.0801 |
| DIFF-CN                                  | 16 | 0.8397  | 3.2983  | 13.44   | -1.2657 | 12.4725 |
| REC-SOIL                                 | 24 | 57.8487 | 11.6315 | 1388.37 | 25.8430 | 74.8180 |
| REC-PLNT                                 | 24 | 20.9239 | 7.2772  | 502.17  | 12.7994 | 35.2407 |
| UNACC                                    | 24 | 1.3091  | 0.1852  | 31.42   | 1.0237  | 1.6447  |
| RESIDUE                                  | 24 | 1.5000  | 0.5108  | 36.00   | 1.0000  | 2.0000  |
| TKN-INIT                                 | 24 | 0.1087  | 0.0202  | 2.61    | 0.0775  | 0.1352  |

CORRELATION COEFF./ PROB &gt; :R: UNDER HO:RHO=0 /NO. OBS.

|          | TKN-FIN | CN-INIT | CN-FIN | DIFF-CN | REC-SOIL | REC-PLNT | UNACC  |
|----------|---------|---------|--------|---------|----------|----------|--------|
| RESIDUE  | 0.017   | 0.000   | -0.003 | 0.139   | -0.598   | 0.864    | 0.209  |
|          | 0.94    | 1.00    | 0.99   | 0.61    | 0.01     | 0.01     | 0.35   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |
| TKN-INIT | 0.759   | -0.011  | 0.096  | 0.260   | 0.196    | 0.317    | -0.502 |
|          | 0.01    | 0.97    | 0.66   | 0.33    | 0.36     | 0.13     | 0.01   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |
| CN-INIT  | 0.051   | 1.000   | -0.004 | -0.320  | -0.092   | 0.071    | 0.058  |
|          | 0.85    | 0.00    | 0.99   | 0.23    | 0.73     | 0.79     | 0.83   |
|          | 16      | 16      | 16     | 16      | 16       | 16       | 16     |
| CN-FIN   | -0.518  | -0.004  | 1.000  | 0.949   | -0.561   | 0.095    | 0.498  |
|          | 0.01    | 0.99    | 0.00   | 0.01    | 0.01     | 0.66     | 0.01   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |
| DIFF-CN  | -0.468  | -0.320  | 0.949  | 1.000   | -0.547   | 0.279    | 0.416  |
|          | 0.07    | 0.23    | 0.01   | 0.00    | 0.03     | 0.30     | 0.11   |
|          | 16      | 16      | 16     | 16      | 16       | 16       | 16     |
| REC-SOIL | 0.542   | -0.092  | -0.561 | -0.547  | 1.000    | -0.571   | -0.762 |
|          | 0.01    | 0.73    | 0.01   | 0.03    | 0.00     | 0.01     | 0.01   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |
| REC-PLNT | 0.251   | 0.071   | 0.095  | 0.279   | -0.571   | 1.000    | 0.073  |
|          | 0.24    | 0.79    | 0.66   | 0.30    | 0.01     | 0.00     | 0.73   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |
| UNACC    | -0.827  | 0.058   | -0.498 | 0.414   | -0.762   | -0.073   | 0.100  |
|          | 0.01    | 0.83    | 0.01   | 0.11    | 0.01     | 0.73     | 0.00   |
|          | 24      | 16      | 24     | 16      | 24       | 24       | 24     |

Table A2.1-continued.

RESIDUE = 1 = GRASS

| VARIABLE | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|---------|---------|---------|---------|
| TKN-FIN  | 12 | 0.1061  | 0.02441 | 1.273   | 0.0574  | 0.1332  |
| CN-INIT  | 8  | 11.8229 | 1.08045 | 94.583  | 9.8952  | 12.9737 |
| CN-FIN   | 12 | 12.5761 | 1.62600 | 150.913 | 11.6556 | 17.2508 |
| DIFF-CN  | 8  | 0.3963  | 1.11272 | 3.170   | -1.2657 | 1.9928  |
| REC-SOIL | 12 | 65.7987 | 8.69138 | 789.584 | 46.8720 | 74.8180 |
| REC-PLNT | 12 | 14.7694 | 1.27927 | 177.233 | 12.7994 | 17.0157 |
| UNACC    | 12 | 1.2712  | 0.18969 | 15.255  | 1.0237  | 1.6035  |
| TKN-INIT | 12 | 0.1087  | 0.02061 | 1.305   | 0.0775  | 0.1352  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 /NO. OBS.

|          | TKN-FIN | CN-INIT | CN-FIN | DIFF-CN | REC-SOIL | REC-PLNT | UNACC  |
|----------|---------|---------|--------|---------|----------|----------|--------|
| TKN-INIT | 0.908   | -0.011  | -0.289 | 0.264   | 0.697    | 0.836    | -0.722 |
|          | 0.01    | 0.98    | 0.36   | 0.53    | 0.01     | 0.01     | 0.01   |
|          | 12      | 8       | 12     | 8       | 12       | 12       | 12     |
| CN-INIT  | -0.049  | 1.000   | 0.340  | -0.720  | -0.425   | -0.004   | 0.320  |
|          | 0.91    | 0.00    | 0.41   | 0.04    | 0.29     | 0.99     | 0.44   |
|          | 8       | 8       | 8      | 8       | 8        | 8        | 8      |
| CN-FIN   | -0.553  | 0.340   | 1.000  | 0.408   | -0.713   | -0.156   | 0.606  |
|          | 0.06    | 0.41    | 0.00   | 0.32    | 0.01     | 0.63     | 0.04   |
|          | 12      | 8       | 12     | 8       | 12       | 12       | 12     |
| DIFF-CN  | 0.094   | -0.720  | 0.408  | 1.000   | 0.141    | 0.164    | -0.052 |
|          | 0.82    | 0.04    | 0.32   | 0.00    | 0.74     | 0.70     | 0.90   |
|          | 8       | 8       | 8      | 8       | 8        | 8        | 8      |
| REC-SOIL | 0.913   | -0.425  | -0.713 | 0.141   | 1.000    | 0.482    | -0.977 |
|          | 0.01    | 0.29    | 0.01   | 0.74    | 0.00     | 0.11     | 0.01   |
|          | 12      | 8       | 12     | 8       | 12       | 12       | 12     |
| REC-PLNT | 0.712   | -0.004  | -0.156 | 0.164   | 0.482    | 1.000    | -0.571 |
|          | 0.01    | 0.99    | 0.63   | 0.70    | 0.11     | 0.00     | 0.05   |
|          | 12      | 8       | 12     | 8       | 12       | 12       | 12     |
| UNACC    | -0.924  | 0.311   | 0.606  | -0.052  | -0.977   | -0.571   | 1.000  |
|          | 0.01    | 0.44    | 0.04   | 0.90    | 0.01     | 0.05     | 0.00   |
|          | 12      | 8       | 12     | 8       | 12       | 12       | 12     |

Table A2.1-continued.

## RESIDUE = 2 = LEGUME

| VARIABLE | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|---------|---------|---------|---------|
| TKN-FIN  | 12 | 0.1069  | 0.02679 | 1.283   | 0.0627  | 0.1381  |
| CN-INIT  | 8  | 11.8229 | 1.08045 | 94.582  | 9.8952  | 12.9737 |
| CN-FIN   | 12 | 12.5585 | 3.65173 | 150.702 | 10.7045 | 24.0801 |
| DIFF-CN  | 8  | 1.2832  | 4.65012 | 10.266  | -1.2119 | 12.4725 |
| REC-SOIL | 12 | 49.8988 | 8.33362 | 598.786 | 25.8430 | 59.2290 |
| REC-PLNT | 12 | 27.0784 | 5.14288 | 324.941 | 16.8046 | 35.2407 |
| UNACC    | 12 | 1.3469  | 0.18051 | 16.163  | 1.0556  | 1.6447  |
| TKN-INIT | 12 | 0.1087  | 0.02061 | 1.305   | 0.0775  | 0.1352  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 /NO. OBS.

|          | TKN-FIN              | CN-INIT             | CN-FIN               | DIFF-CN             | REC-SOIL             | REC-PLNT             | UNACC                |
|----------|----------------------|---------------------|----------------------|---------------------|----------------------|----------------------|----------------------|
| TKN-INIT | 0.624<br>0.03<br>12  | -0.011<br>0.98<br>8 | 0.280<br>0.38<br>12  | 0.319<br>0.44<br>8  | -0.167<br>0.60<br>12 | 0.710<br>0.01<br>12  | -0.293<br>0.35<br>12 |
| CN-INIT  | 0.128<br>0.76<br>8   | 1.000<br>0.00<br>8  | -0.068<br>0.87<br>8  | -0.298<br>0.47<br>8 | 0.067<br>0.87<br>8   | 0.185<br>0.66<br>8   | -0.209<br>0.62<br>8  |
| CN-FIN   | -0.543<br>0.07<br>12 | -0.068<br>0.87<br>8 | 1.000<br>0.00<br>12  | 0.973<br>0.01<br>8  | -0.913<br>0.01<br>12 | 0.237<br>0.46<br>12  | 0.526<br>0.08<br>12  |
| DIFF-CN  | -0.616<br>0.10<br>8  | -0.298<br>0.47<br>8 | 0.973<br>0.01<br>8   | 1.000<br>0.00<br>8  | -0.936<br>0.01<br>8  | 0.302<br>0.47<br>8   | 0.607<br>0.11<br>8   |
| REC-SOIL | 0.644<br>0.02<br>12  | 0.067<br>0.87<br>8  | -0.913<br>0.01<br>12 | -0.936<br>0.01<br>8 | 1.000<br>0.00<br>12  | 0.009<br>0.98<br>12  | -0.773<br>0.01<br>12 |
| REC-PLNT | 0.492<br>0.10<br>12  | 0.185<br>0.66<br>8  | 0.237<br>0.46<br>12  | 0.302<br>0.47<br>8  | 0.009<br>0.98<br>12  | 1.000<br>0.00<br>12  | -0.620<br>0.03<br>12 |
| UNACC    | -0.781<br>0.01<br>12 | -0.209<br>0.62<br>8 | 0.526<br>0.08<br>12  | 0.607<br>0.11<br>8  | -0.773<br>0.01<br>12 | -0.620<br>0.03<br>12 | 1.000<br>0.00<br>12  |

Table A2.2 - Analysis of variance for LA soil.

| DEPENDENT VARIABLE: REC-SOIL |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 11 | 2522.33919883   | 229.30356353 |
| ERROR                        | 12 | 589.57088567    | 49.11424047  |
| CORRECTED TOTAL              | 23 | 3111.71008450   |              |
| MODEL F = 4.67               |    | PR > F = 0.0066 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-SOIL MEAN |
|----------|---------|------------|---------------|
| 0.810596 | 12.1146 | 7.00815528 | 57.84875000   |

| SOURCE             | DF | TYPE IV SS    | PR > F |
|--------------------|----|---------------|--------|
| REP                | 2  | 113.40686275  | 0.3479 |
| RESIDUE            | 1  | 1516.82820017 | 0.0001 |
| REP*RESIDUE        | 2  | 167.13487558  | 0.2236 |
| MANAGEMENT         | 3  | 321.18421350  | 0.1434 |
| MANAGEMENT*RESIDUE | 3  | 405.78504683  | 0.0895 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS    | PR > F |
|---------|----|---------------|--------|
| RESIDUE | 1  | 1516.82820017 | 0.0509 |

| DEPENDENT VARIABLE: REC-PLNT |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 11 | 1165.43274444   | 105.76661313 |
| ERROR                        | 12 | 54.58116072     | 4.54843006   |
| CORRECTED TOTAL              | 23 | 1218.01390516   |              |
| MODEL F = 23.25              |    | PR > F = 0.0001 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-PLNT MEAN |
|----------|---------|------------|---------------|
| 0.955186 | 10.1927 | 2.13270487 | 20.92394583   |

| SOURCE             | DF | TYPE IV SS   | PR > F |
|--------------------|----|--------------|--------|
| REP                | 2  | 30.7673141   | 0.0705 |
| RESIDUE            | 1  | 909.07011690 | 0.0001 |
| REP*RESIDUE        | 2  | 27.44782470  | 0.0868 |
| MANAGEMENT         | 3  | 144.90152488 | 0.0011 |
| MANAGEMENT*RESIDUE | 3  | 51.63654655  | 0.0403 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS   | PR > F |
|---------|----|--------------|--------|
| RESIDUE | 1  | 909.07011690 | 0.0148 |

Table A2.2-continued.

| DEPENDENT VARIABLE: UNACC |    |                 |             |
|---------------------------|----|-----------------|-------------|
| SOURCE                    | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                     | 11 | 0.59576488      | 0.05416044  |
| ERROR                     | 12 | 0.19279085      | 0.01606590  |
| CORRECTED TOTAL           | 23 | 0.78855573      |             |
| MODEL F = 3.37            |    | PR > F = 0.0237 |             |

| R-SQUARE | C.V.   | ROOT MSE   | UNACC MEAN |
|----------|--------|------------|------------|
| 0.755514 | 9.6824 | 0.12675135 | 1.30908421 |

| SOURCE             | DF | TYPE IV SS | PR > F |
|--------------------|----|------------|--------|
| REP                | 2  | 0.09967823 | 0.0820 |
| RESIDUE            | 1  | 0.03435964 | 0.1693 |
| REP*RESIDUE        | 2  | 0.08400656 | 0.1142 |
| MANAGEMENT         | 3  | 0.30595001 | 0.0080 |
| MANAGEMENT*RESIDUE | 3  | 0.07177044 | 0.2673 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.03435964 | 0.4612 |

Table A2.2-continued.

| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 11 | 0.00912958      | 0.00082997  |
| ERROR                        | 12 | 0.00021255      | 0.00001771  |
| CORRECTED TOTAL              | 23 | 0.00934223      |             |
| MODEL F = 46.86              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
|----------|--------|------------|---------------|
| 0.977248 | 3.8714 | 0.00420865 | 0.10871258    |

| SOURCE             | DF | TYPE IV SS | PR > F |
|--------------------|----|------------|--------|
| REP                | 2  | 0.00025524 | 0.0088 |
| RESIDUE            | 1  | 0.00000000 | 1.0000 |
| REP*RESIDUE        | 2  | 0.00000000 | 1.0000 |
| MANAGEMENT         | 3  | 0.00887444 | 0.0001 |
| MANAGEMENT*RESIDUE | 3  | 0.00000000 | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00000000 |        |

| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 11 | 0.01122273      | 0.00102025  |
| ERROR                       | 12 | 0.00322880      | 0.00026907  |
| CORRECTED TOTAL             | 23 | 0.01445153      |             |
| MODEL F = 3.79              |    | PR > F = 0.0152 |             |

| R-SQUARE | C.V.    | ROOT MSE   | TKN-FIN MEAN |
|----------|---------|------------|--------------|
| 0.776577 | 15.4002 | 0.01640325 | 0.10651304   |

| SOURCE             | DF | TYPE IV SS | PR > F |
|--------------------|----|------------|--------|
| REP                | 2  | 0.00022823 | 0.6638 |
| RESIDUE            | 1  | 0.00000412 | 0.9036 |
| REP*RESIDUE        | 2  | 0.00053791 | 0.3967 |
| MANAGEMENT         | 3  | 0.00974919 | 0.0006 |
| MANAGEMENT*RESIDUE | 3  | 0.00070328 | 0.4928 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00000412 | 0.9128 |

Table A2.2-continued.

| DEPENDENT VARIABLE: CN-INIT |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 9  | 15.74316060     | 1.75035118  |
| ERROR                       | 6  | 0.58992019      | 0.09832005  |
| CORRECTED TOTAL             | 15 | 16.34308079     |             |
| MODEL F = 17.80             |    | PR > F = 0.0011 |             |

| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
|----------|--------|------------|--------------|
| 0.963904 | 2.6521 | 0.31356025 | 11.82292500  |

| SOURCE             | DF | TYPE IV SS  | PR > F |
|--------------------|----|-------------|--------|
| REP                | 1  | 2.62148481  | 0.0021 |
| RESIDUE            | 1  | 0.00000000  | 1.0000 |
| REP*RESIDUE        | 1  | 0.00000000  | 1.0000 |
| MANAGEMENT         | 3  | 13.13167579 | 0.0002 |
| MANAGEMENT*RESIDUE | 3  | 0.00000000  | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00000000 |        |

| DEPENDENT VARIABLE: CN-FIN |    |                 |             |
|----------------------------|----|-----------------|-------------|
| SOURCE                     | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                      | 11 | 75.65413395     | 6.87764854  |
| ERROR                      | 12 | 100.11674451    | 8.34306204  |
| CORRECTED TOTAL            | 23 | 175.77087846    |             |
| MODEL F = 0.82             |    | PR > F = 0.6220 |             |

| R-SQUARE | C.V.    | ROOT MSE   | CN-FIN MEAN |
|----------|---------|------------|-------------|
| 0.430413 | 22.9838 | 2.88843592 | 12.56729167 |

| SOURCE             | DF | TYPE IV SS  | PR > F |
|--------------------|----|-------------|--------|
| REP                | 2  | 6.14784709  | 0.6994 |
| RESIDUE            | 1  | 0.00184451  | 0.9884 |
| REP*RESIDUE        | 2  | 18.95355608 | 0.3534 |
| MANAGEMENT         | 3  | 20.37818810 | 0.5103 |
| MANAGEMENT*RESIDUE | 3  | 30.17269816 | 0.3497 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00184451 | 0.9901 |

Table A2.3 - One degree of freedom contrasts for LA soil.

| DEPENDENT VARIABLE: REC-SOIL |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 7  | 2241.79746050   | 320.25678007 |
| ERROR                        | 16 | 869.91262400    | 54.36953900  |
| CORRECTED TOTAL              | 23 | 3111.71008450   |              |
| MODEL F = 5.89               |    | PR > F = 0.0016 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-SOIL MEAN |
|----------|---------|------------|---------------|
| 0.720439 | 12.7463 | 7.37357030 | 57.84875000   |

| SOURCE | DF | TYPE IV SS    | PR > F |
|--------|----|---------------|--------|
| TRT    | 7  | 2241.79746050 | 0.0016 |

| CONTRAST            | DF | SS           | PR > F |
|---------------------|----|--------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 560.45827600 | 0.0055 |
| 2:L-VIRG VS CROPPED | 1  | 0.98208100   | 0.8948 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 1.33824800   | 0.8773 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 40.33816200  | 0.4018 |
| 5:G-HIGH2 VS HIGH3  | 1  | 40.53920267  | 0.4006 |
| 6:L-HIGH2 VS HIGH3  | 1  | 81.31329067  | 0.2391 |

| DEPENDENT VARIABLE: REC-PLNT |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 7  | 1105.60818833   | 157.94402690 |
| ERROR                        | 16 | 112.40571683    | 7.02535730   |
| CORRECTED TOTAL              | 23 | 1218.01390516   |              |
| MODEL F = 22.48              |    | PR > F = 0.0001 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-PLNT MEAN |
|----------|---------|------------|---------------|
| 0.907714 | 12.6675 | 2.65053906 | 20.92394583   |

| SOURCE | DF | TYPE IV SS    | PR > F |
|--------|----|---------------|--------|
| TRT    | 7  | 1105.60818833 | 0.0001 |

| CONTRAST            | DF | SS           | PR > F |
|---------------------|----|--------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 9.76614584   | 0.2556 |
| 2:L-VIRG VS CROPPED | 1  | 135.92684019 | 0.0004 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 1.06852708   | 0.7017 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 41.43442856  | 0.0273 |
| 5:G-HIGH2 VS HIGH3  | 1  | 1.97157873   | 0.6036 |
| 6:L-HIGH2 VS HIGH3  | 1  | 6.37055104   | 0.3551 |

Table A2.3-continued.

| DEPENDENT VARIABLE: UNACC |         |                 |             |
|---------------------------|---------|-----------------|-------------|
| SOURCE                    | DF      | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                     | 7       | 0.41208009      | 0.05886858  |
| ERROR                     | 16      | 0.37647564      | 0.02352973  |
| CORRECTED TOTAL           | 23      | 0.78855573      |             |
| MODEL F = 2.50            |         | PR > F = 0.0610 |             |
| R-SQUARE                  | C.V.    | ROOT MSE        | LNACC MEAN  |
| 0.522576                  | 11.7177 | 0.15339403      | 1.30908421  |
| SOURCE                    | DF      | TYPE IV SS      | PR > F      |
| TRT                       | 7       | 0.41208009      | 0.0610      |
| CONTRAST                  | DF      |                 | PR > F      |
| 1:G-VIRG VS CROPPED       | 1       | 0.25907040      | 0.0043      |
| 2:L-VIRG VS CROPPED       | 1       | 0.06806990      | 0.1083      |
| 3:G-LOW1 VS HIGH2&3       | 1       | 0.00533138      | 0.6409      |
| 4:L-LOW1 VS HIGH2&3       | 1       | 0.00262248      | 0.7428      |
| 5:G-HIGH2 VS HIGH3        | 1       | 0.01256906      | 0.4751      |
| 6:L-HIGH2 VS HIGH3        | 1       | 0.03003723      | 0.2752      |

Table A2.3-continued.

| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SJM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 7  | 0.00887444      | 0.00126778  |
| ERROR                        | 16 | 0.00046779      | 0.00002924  |
| CORRECTED TOTAL              | 23 | 0.00934223      |             |
| MODEL F = 43.36              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
|----------|--------|------------|---------------|
| 0.949928 | 4.9738 | 0.00540711 | 0.10871258    |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 7  | 0.00887444 | 0.0001 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 0.00355174 | 0.0001 |
| 2:L-VIRG VS CROPPED | 1  | 0.00355174 | 0.0001 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 0.00083812 | 0.0001 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 0.00083812 | 0.0001 |
| 5:G-HIGH2 VS HIGH3  | 1  | 0.00004735 | 0.2213 |
| 6:L-HIGH2 VS HIGH3  | 1  | 0.00004735 | 0.2213 |

| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 7  | 0.01045659      | 0.00149380  |
| ERROR                       | 16 | 0.00399494      | 0.00024968  |
| CORRECTED TOTAL             | 23 | 0.01445153      |             |
| MODEL F = 5.98              |    | PR > F = 0.0015 |             |

| R-SQUARE | C.V.    | ROOT MSE   | TKN-FIN MEAN |
|----------|---------|------------|--------------|
| 0.723563 | 14.8352 | 0.01580139 | 0.10651304   |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 7  | 0.01045659 | 0.0015 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 0.00510796 | 0.0003 |
| 2:L-VIRG VS CROPPED | 1  | 0.00339634 | 0.0020 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 0.00071431 | 0.1101 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 0.00032907 | 0.2678 |
| 5:G-HIGH2 VS HIGH3  | 1  | 0.00001820 | 0.7906 |
| 6:L-HIGH2 VS HIGH3  | 1  | 0.00088659 | 0.0778 |

Table A2.3-continued.

| DEPENDENT VARIABLE: CN-INIT |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 7  | 13.13167579     | 1.87595368  |
| ERROR                       | 8  | 3.21140500      | 0.40142563  |
| CORRECTED TOTAL             | 13 | 16.34308079     |             |
| MODEL F = 4.67              |    | PR > F = 0.0229 |             |

| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
|----------|--------|------------|--------------|
| 0.803501 | 5.3589 | 0.63358159 | 11.82292500  |

| SOURCE | DF | TYPE IV SS  | PR > F |
|--------|----|-------------|--------|
| TRT    | 7  | 13.13167579 | 0.0229 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRC VS CROPPED | 1  | 0.92112180 | 0.1683 |
| 2:L-VIRC VS CROPPED | 1  | 0.92112180 | 0.1683 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 5.64276245 | 0.0056 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 5.64276245 | 0.0056 |
| 5:G-HIGH2 VS HIGH3  | 1  | 0.00195364 | 0.9461 |
| 6:L-HIGH2 VS HIGH3  | 1  | 0.00195364 | 0.9461 |

| DEPENDENT VARIABLE: CN-FIN |    |                 |             |
|----------------------------|----|-----------------|-------------|
| SOURCE                     | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                      | 7  | 50.55273077     | 7.22181868  |
| ERROR                      | 16 | 125.21814769    | 7.82613423  |
| CORRECTED TOTAL            | 23 | 175.77087846    |             |
| MODEL F = 0.92             |    | PR > F = 0.5148 |             |

| R-SQUARE | C.V.    | ROOT MSE   | CN-FIN MEAN |
|----------|---------|------------|-------------|
| 0.287606 | 22.2603 | 2.79752287 | 12.56729167 |

| SOURCE | DF | TYPE IV SS  | PR > F |
|--------|----|-------------|--------|
| TRT    | 7  | 50.55273077 | 0.5148 |

| CONTRAST            | DF | SS          | PR > F |
|---------------------|----|-------------|--------|
| 1:G-VIRC VS CROPPED | 1  | 4.93646930  | 0.4387 |
| 2:L-VIRC VS CROPPED | 1  | 2.91447493  | 0.5503 |
| 3:G-LOW1 VS HIGH2&3 | 1  | 0.88626860  | 0.7409 |
| 4:L-LOW1 VS HIGH2&3 | 1  | 10.34018129 | 0.2673 |
| 5:G-HIGH2 VS HIGH3  | 1  | 0.55200600  | 0.7940 |
| 6:L-HIGH2 VS HIGH3  | 1  | 30.92148613 | 0.0642 |

Table A2.4 - Correlations for LE soil.

| CORRELATIONS WITH BOTH RESIDUES COMBINED |    |         |         |         |         |         |
|------------------------------------------|----|---------|---------|---------|---------|---------|
| VARIABLE                                 | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
| TKN-FIN                                  | 36 | 0.1219  | 0.00692 | 4.39    | 0.1036  | 0.1352  |
| CN-INIT                                  | 24 | 10.2596 | 0.64317 | 246.23  | 9.1389  | 11.5022 |
| CN-FIN                                   | 36 | 10.9586 | 0.57267 | 394.51  | 9.4622  | 12.0785 |
| DIFF-CN                                  | 24 | 0.7864  | 0.99500 | 18.87   | -1.6770 | 2.7753  |
| REC-SOIL                                 | 36 | 61.8530 | 7.85546 | 2226.71 | 46.8550 | 72.2340 |
| REC-PLNT                                 | 33 | 19.3677 | 6.68571 | 639.13  | 10.6866 | 31.1801 |
| UNACC                                    | 33 | 1.2686  | 0.10101 | 41.86   | 1.0329  | 1.4981  |
| RESIDUE                                  | 36 | 1.5000  | 0.50709 | 54.00   | 1.0000  | 2.0000  |
| TKN-INIT                                 | 36 | 0.1201  | 0.00872 | 4.32    | 0.1025  | 0.1302  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 /NO. OBS.

|          | TKN-FIN              | CN-INIT              | CN-FIN               | DIFF-CN              | REC-SOIL             | REC-PLNT             | UNACC                |
|----------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| RESIDUE  | 0.346<br>0.04<br>36  | 0.000<br>1.00<br>24  | -0.258<br>0.13<br>26 | -0.150<br>0.48<br>24 | -0.893<br>0.01<br>36 | 0.944<br>0.01<br>33  | 0.038<br>0.84<br>33  |
| TKN-INIT | 0.598<br>0.01<br>36  | -0.471<br>0.02<br>24 | 0.257<br>0.13<br>36  | 0.432<br>0.03<br>24  | -0.140<br>0.42<br>36 | 0.009<br>0.96<br>33  | 0.055<br>0.76<br>33  |
| CN-INIT  | -0.256<br>0.23<br>24 | 1.000<br>0.00<br>24  | -0.258<br>0.22<br>24 | -0.805<br>0.01<br>24 | 0.173<br>0.42<br>24  | 0.061<br>0.79<br>22  | -0.211<br>0.35<br>22 |
| CN-FIN   | -0.400<br>0.02<br>36 | -0.258<br>0.22<br>24 | 1.000<br>0.00<br>35  | 0.781<br>0.01<br>24  | -0.048<br>0.78<br>36 | -0.312<br>0.87<br>33 | 0.371<br>0.03<br>33  |
| DIFF-CN  | -0.087<br>0.69<br>24 | -0.805<br>0.01<br>24 | 0.781<br>0.01<br>24  | 1.000<br>0.00<br>24  | -0.134<br>0.53<br>24 | -0.254<br>0.25<br>22 | 0.550<br>0.11<br>22  |
| REC-SOIL | -0.141<br>0.41<br>36 | 0.173<br>0.42<br>24  | -0.048<br>0.78<br>36 | -0.134<br>0.53<br>24 | 1.000<br>0.00<br>36  | -0.806<br>0.01<br>33 | -0.430<br>0.01<br>33 |
| REC-PLNT | 0.456<br>0.08<br>33  | 0.061<br>0.79<br>22  | -0.312<br>0.08<br>33 | -0.254<br>0.25<br>22 | -0.806<br>0.01<br>33 | 1.000<br>0.00<br>33  | -0.178<br>0.32<br>33 |
| UNACC    | -0.506<br>0.01<br>33 | -0.211<br>0.35<br>22 | 0.371<br>0.03<br>33  | 0.550<br>0.11<br>22  | -0.430<br>0.01<br>33 | -0.178<br>0.32<br>33 | 1.000<br>0.00<br>33  |

Table A2.4-continued.

RESIDUE = 1 = GRASS

| VARIABLE | N  | MEAN    | STD DEV  | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|----------|---------|---------|---------|
| TKN-FIN  | 18 | 0.1195  | 0.00671  | 2.15    | 0.1036  | 0.1292  |
| CN-INIT  | 12 | 10.2596 | 0.065762 | 123.12  | 9.1389  | 11.5022 |
| CN-FIN   | 18 | 11.1044 | 0.37027  | 199.88  | 10.2334 | 11.9142 |
| DIFF-CN  | 12 | 0.9327  | 0.84502  | 11.19   | -0.6705 | 2.7753  |
| REC-SOIL | 18 | 68.7529 | 1.17857  | 1237.57 | 64.8860 | 72.2340 |
| REC-PLNT | 18 | 13.6931 | 1.71380  | 246.47  | 10.6866 | 16.3086 |
| UNACC    | 18 | 1.2652  | 0.05449  | 22.77   | 1.1502  | 1.3782  |
| TKN-INIT | 18 | 0.1201  | 0.00885  | 2.16    | 0.1025  | 0.1302  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 /NO. OBS.

|          | TKN-FIN | CN-INIT | CN-FIN | DIFF-CN | REC-SOIL | REC-PLNT | UNACC  |
|----------|---------|---------|--------|---------|----------|----------|--------|
| TKN-INIT | 0.843   | -0.471  | 0.451  | 0.472   | -0.168   | 0.916    | -0.540 |
|          | 0.01    | 0.12    | 0.06   | 0.12    | 0.51     | 0.01     | 0.02   |
|          | 18      | 12      | 18     | 12      | 18       | 18       | 18     |
| CN-INIT  | -0.358  | 1.000   | -0.337 | -0.917  | -0.690   | -0.388   | -0.324 |
|          | 0.256   | 0.00    | 0.30   | 0.01    | 0.01     | 0.21     | 0.30   |
|          | 12      | 12      | 12     | 12      | 12       | 12       | 12     |
| CN-FIN   | -0.038  | -0.337  | 1.000  | 0.678   | -0.584   | 0.411    | 0.139  |
|          | 0.88    | 0.30    | 0.00   | 0.02    | 0.01     | 0.09     | 0.58   |
|          | 18      | 12      | 18     | 12      | 18       | 18       | 18     |
| DIFF-CN  | 0.212   | -0.917  | -0.678 | 1.000   | -0.848   | -0.416   | 0.453  |
|          | 0.51    | 0.01    | 0.02   | 0.00    | 0.01     | 0.18     | 0.14   |
|          | 12      | 12      | 12     | 12      | 12       | 12       | 12     |
| REC-SOIL | 0.088   | 0.690   | -0.584 | -0.848  | 1.000    | -0.119   | -0.690 |
|          | 0.73    | 0.01    | 0.01   | 0.01    | 0.00     | 0.64     | 0.01   |
|          | 18      | 12      | 18     | 12      | 18       | 18       | 18     |
| REC-PLNT | 0.786   | -0.388  | 0.411  | 0.415   | -0.119   | 1.000    | 0.632  |
|          | 0.01    | 0.21    | 0.09   | 0.18    | 0.64     | 0.00     | 0.01   |
|          | 18      | 12      | 18     | 12      | 18       | 18       | 18     |
| UNACC    | -0.635  | -0.324  | 0.139  | 0.453   | -0.690   | -0.632   | 1.000  |
|          | 0.01    | 0.30    | 0.58   | 0.14    | 0.01     | 0.01     | 0.00   |
|          | 18      | 12      | 18     | 12      | 18       | 18       | 18     |

Table A2.4-continued.

RESIDUE = 2 = LEGUME

| VARIABLE | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|---------|---------|---------|---------|
| TKN-FIN  | 18 | 0.1242  | 0.00647 | 2.235   | 0.1133  | 0.1352  |
| CN-INIT  | 12 | 10.2596 | 0.65762 | 123.116 | 9.1389  | 11.5022 |
| CN-FIN   | 18 | 10.8128 | 0.70218 | 194.630 | 9.4622  | 12.0785 |
| DIFF-CN  | 12 | 0.6402  | 1.14426 | 7.682   | -1.6770 | 2.3281  |
| REC-SOIL | 18 | 54.9522 | 4.73074 | 989.139 | 46.8550 | 64.2350 |
| REC-PLNT | 15 | 26.1773 | 2.74179 | 392.659 | 20.6328 | 31.1801 |
| UNACC    | 15 | 1.2727  | 0.14030 | 19.091  | 1.0329  | 1.4981  |
| TKN-INIT | 18 | 0.1201  | 0.00885 | 2.162   | 0.1025  | 0.1302  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 / NO. OBS.

|          | TKN-FIN              | CN-INIT              | CN-FIN               | DIFF-CN              | REC-SOIL             | REC-PLNT             | LNACC                |
|----------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| TKN-INIT | 0.422<br>0.08<br>18  | -0.471<br>0.12<br>12 | 0.188<br>0.46<br>18  | 0.421<br>0.17<br>12  | -0.408<br>0.09<br>18 | -0.060<br>0.83<br>15 | 0.367<br>0.18<br>15  |
| CN-INIT  | -0.182<br>0.57<br>12 | 1.000<br>0.00<br>12  | -0.262<br>0.41<br>12 | -0.753<br>0.01<br>12 | 0.348<br>0.27<br>12  | -0.094<br>0.80<br>10 | -0.227<br>0.53<br>10 |
| CN-FIN   | -0.538<br>0.02<br>18 | -0.262<br>0.41<br>12 | 1.000<br>0.00<br>18  | 0.832<br>0.01<br>12  | -0.659<br>0.01<br>18 | -0.092<br>0.74<br>15 | 0.483<br>0.07<br>15  |
| DIFF-CN  | -0.241<br>0.45<br>12 | -0.753<br>0.01<br>12 | 0.832<br>0.01<br>12  | 1.000<br>0.00<br>12  | -0.620<br>0.03<br>12 | -0.012<br>0.97<br>10 | 0.398<br>0.26<br>10  |
| REC-SOIL | 0.577<br>0.01<br>18  | 0.348<br>0.27<br>12  | -0.659<br>0.01<br>18 | -0.620<br>0.03<br>12 | 1.000<br>0.00<br>18  | 0.574<br>0.17<br>15  | -0.920<br>0.01<br>15 |
| REC-PLNT | 0.396<br>0.14<br>15  | -0.094<br>0.80<br>10 | -0.92<br>0.74<br>15  | -0.012<br>0.97<br>10 | 0.374<br>0.17<br>15  | 1.000<br>0.00<br>15  | -0.672<br>0.01<br>15 |
| UNACC    | -0.604<br>0.02<br>15 | -0.227<br>0.53<br>10 | 0.483<br>0.07<br>15  | 0.398<br>0.26<br>10  | -0.920<br>0.01<br>15 | -0.672<br>0.07<br>15 | 1.000<br>0.01<br>15  |

Table A2.5 - Analysis of variance for LE soil.

| DEPENDENT VARIABLE: REC-SOIL |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 15 | 1955.00089275   | 130.33339285 |
| ERROR                        | 20 | 193.80260622    | 9.69013031   |
| CORRECTED TOTAL              | 35 | 2148.80349897   |              |
| MODEL F = 13.45              |    | PR > F = 0.0001 |              |

| R-SQUARE | C.V.   | ROOT MSE   | REC-SOIL MEAN |
|----------|--------|------------|---------------|
| 0.909809 | 5.0327 | 3.11289741 | 61.89302778   |

| SOURCE             | DF | TYPE IV SS    | PR > F |
|--------------------|----|---------------|--------|
| REP                | 2  | 29.15499939   | 0.2462 |
| RESIDUE            | 1  | 1714.38782669 | 0.0001 |
| REP*RESIDUE        | 2  | 9.79918106    | 0.6106 |
| MANAGEMENT         | 5  | 108.19912414  | 0.0909 |
| MANAGEMENT*RESIDUE | 5  | 93.45976147   | 0.1343 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS    | PR > F |
|---------|----|---------------|--------|
| RESIDUE | 1  | 1714.38782669 | 0.0028 |

| DEPENDENT VARIABLE: REC-PLNT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 14 | 1385.89586162   | 98.99256154 |
| ERROR                        | 18 | 44.46172072     | 2.47009560  |
| CORRECTED TOTAL              | 32 | 1430.35758234   |             |
| MODEL F = 40.08              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | REC-PLNT MEAN |
|----------|--------|------------|---------------|
| 0.968916 | 8.1148 | 1.57165378 | 19.36770000   |

| SOURCE             | DF | TYPE I SS     | PR > F |
|--------------------|----|---------------|--------|
| REP                | 2  | 9.68117913    | 0.1698 |
| RESIDUE            | 1  | 1275.18294701 | 0.0001 |
| REP*RESIDUE        | 2  | 10.88624889   | 1.1393 |
| MANAGEMENT         | 5  | 39.44828528   | 0.0308 |
| MANAGEMENT*RESIDUE | 4  | 50.69720120   | 0.0061 |

| SOURCE             | DF | TYPE IV SS    | PR > F |
|--------------------|----|---------------|--------|
| REP                | 2  | 11.54205162   | 0.1253 |
| RESIDUE            | 1* | 1260.13842008 | 0.0001 |
| REP*RESIDUE        | 2  | 10.88624889   | 0.1393 |
| MANAGEMENT         | 5* | 60.37152216   | 0.0053 |
| MANAGEMENT*RESIDUE | 4  | 50.69720120   | 0.0061 |

\* NOTE. OTHER TYPE IV TESTABLE HYPOTHESES EXIST WHICH MAY YIELD DIFFERENCE SS.

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS    | PR > F |
|---------|----|---------------|--------|
| RESIDUE | 1* | 1260.13842008 | 0.0043 |

Table A2.5-continued.

| DEPENDENT VARIABLE: UNACC |    |                 |             |
|---------------------------|----|-----------------|-------------|
| SOURCE                    | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                     | 14 | 0.14895269      | 0.01063948  |
| ERROR                     | 19 | 0.17754132      | 0.00986341  |
| CORRECTED TOTAL           | 32 | 0.32649401      |             |
| MODEL F = 1.08            |    | PR > F = 0.4328 |             |

|          |        |            |            |
|----------|--------|------------|------------|
| R-SQUARE | C.V.   | ROOT MSE   | UNACC MEAN |
| 0.456219 | 7.8286 | 0.09931469 | 1.26861259 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE I SS  | PR > F |
| REP                | 2  | 0.00458045 | 0.7951 |
| RESIDUE            | 1  | 0.00046053 | 0.8314 |
| REP*RESIDUE        | 2  | 0.00252834 | 0.8805 |
| MANAGEMENT         | 5  | 0.03497983 | 0.6242 |
| MANAGEMENT*RESIDUE | 4  | 0.10640354 | 0.0639 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 2  | 0.00464126 | 0.7927 |
| RESIDUE            | 1* | 0.00021276 | 0.8849 |
| REP*RESIDUE        | 2  | 0.00252834 | 0.8805 |
| MANAGEMENT         | 5* | 0.04543375 | 0.4898 |
| MANAGEMENT*RESIDUE | 4  | 0.10640354 | 0.0639 |

\* NOTE: OTHER TYPE IV TESTABLE HYPOTHESES EXIST WHICH MAY  
YIELD DIFFERENCE SS.

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS  
AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1* | 0.00021276 | 0.7214 |

Table A2.5-continued.

| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 15 | 0.00256456      | 0.00017097  |
| ERROR                        | 20 | 0.00009825      | 0.00000491  |
| CORRECTED TOTAL              | 35 | 0.00266281      |             |
| MODEL F = 34.80              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
|----------|--------|------------|---------------|
| 0.963102 | 1.8452 | 0.00221644 | 0.12011789    |

| SOURCE             | DF | TYPE IV SS | PR > F |
|--------------------|----|------------|--------|
| REP                | 2  | 0.00000228 | 0.7949 |
| RESIDUE            | 1  | 0.00000000 | 1.0000 |
| REP*RESIDUE        | 2  | 0.00000000 | 1.0000 |
| MANAGEMENT         | 5  | 0.00256228 | 0.0001 |
| MANAGEMENT*RESIDUE | 5  | 0.00000000 | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00000000 |        |

| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 15 | 0.00117647      | 0.00007843  |
| ERROR                       | 20 | 0.00049916      | 0.00002496  |
| CORRECTED TOTAL             | 35 | 0.00167563      |             |
| MODEL F = 3.14              |    | PR > F = 0.0091 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-FIN MEAN |
|----------|--------|------------|--------------|
| 0.702105 | 4.0987 | 0.00499582 | 0.12188656   |

| SOURCE             | DF | TYPE IV SS | PR > F |
|--------------------|----|------------|--------|
| REP                | 2  | 0.00007559 | 0.2441 |
| RESIDUE            | 1  | 0.00020006 | 0.0103 |
| REP*RESIDUE        | 2  | 0.00002564 | 0.6060 |
| MANAGEMENT         | 5  | 0.00072215 | 0.0018 |
| MANAGEMENT*RESIDUE | 5  | 0.00015303 | 0.3534 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS | PR > F |
|---------|----|------------|--------|
| RESIDUE | 1  | 0.00020006 | 0.0585 |

Table A2.5-continued.

| DEPENDENT VARIABLE: CN-INIT |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 13 | 7.02761047      | 0.54058542  |
| ERROR                       | 10 | 2.48672427      | 0.24867243  |
| CORRECTED TOTAL             | 23 | 9.51433474      |             |
| MODEL F = 2.17              |    | PR > F = 0.1120 |             |

|          |        |            |              |
|----------|--------|------------|--------------|
| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
| 0.738634 | 4.8605 | 0.49867066 | 10.25964167  |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 1  | 0.08884100 | 0.5633 |
| RESIDUE            | 1  | 0.00000000 | 1.0000 |
| REP*RESIDUE        | 1  | 0.00000000 | 1.0000 |
| MANAGEMENT         | 5  | 6.93876947 | 0.0103 |
| MANAGEMENT*RESIDUE | 5  | 0.00000000 | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 0.00000000 |        |

| DEPENDENT VARIABLE: CN-FIN |    |                 |             |
|----------------------------|----|-----------------|-------------|
| SOURCE                     | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                      | 15 | 4.55135866      | 0.30342391  |
| ERROR                      | 20 | 6.92703215      | 0.34635161  |
| CORRECTED TOTAL            | 35 | 11.47839081     |             |
| MODEL F = 0.88             |    | PR > F = 0.5971 |             |

|          |        |            |             |
|----------|--------|------------|-------------|
| R-SQUARE | C.V.   | ROOT MSE   | CN-FIN MEAN |
| 0.596515 | 5.3704 | 0.58851645 | 10.95861667 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 2  | 0.85509018 | 0.3122 |
| RESIDUE            | 1  | 0.76562500 | 0.1527 |
| REP*RESIDUE        | 2  | 0.26963361 | 0.6826 |
| MANAGEMENT         | 5  | 2.08317134 | 0.3435 |
| MANAGEMENT*RESIDUE | 5  | 0.57783853 | 0.8866 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 0.76562500 | 0.1400 |

Table A2.6 - One degree of freedom contrasts for LE soil.

| DEPENDENT VARIABLE: REC-SOIL |        |                 |               |
|------------------------------|--------|-----------------|---------------|
| SOURCE                       | DF     | SUM OF SQUARES  | MEAN SQUARE   |
| MODEL                        | 11     | 1916.04671231   | 174.18606476  |
| ERROR                        | 24     | 232.75578667    | 9.69819944    |
| CORRECTED TOTAL              | 35     | 2148.80349897   |               |
| MODEL F = 17.96              |        | PR > F = 0.0001 |               |
| R-SQUARE                     | C.V.   | ROOT MSE        | REC-SOIL MEAN |
| 0.891681                     | 5.0348 | 3.11419323      | 61.85302778   |
| SOURCE                       | DF     | TYPE IV SS      | PR > F        |
| TRT                          | 11     | 1916.04671231   | 0.0001        |
| CONTRAST                     | DF     | SS              | PR > F        |
| 1:G-VIRG VS CROPPED          | 1      | 15.24096000     | 0.2221        |
| 2:L-VIRG VS CROPPED          | 1      | 2.07985402      | 0.6475        |
| 3:G-VIRG VS NGPU             | 1      | 3.48081667      | 0.5547        |
| 4:L-VIRG VS NGPU             | 1      | 8.69288067      | 0.3552        |
| 5:G-CA1 VS CA2               | 1      | 0.25872033      | 0.8716        |
| 6:L-CA1 VS CA2               | 1      | 5.32400408      | 0.4659        |
| 7:G-CA1PO VS CA1P1           | 1      | 4.25546817      | 0.5140        |
| 8:L-CA1PO VS CA1P1           | 1      | 47.90070150     | 0.0359        |
| 9:G-CA2PO VS CA2P1           | 1      | 2.44609350      | 0.6201        |
| 10:L-CA2PO VS CA2P1          | 1      | 116.65568600    | 0.0020        |
| DEPENDENT VARIABLE: REC-PLNT |        |                 |               |
| SOURCE                       | DF     | SUM OF SQUARES  | MEAN SQUARE   |
| MODEL                        | 10     | 1365.32843349   | 136.53284335  |
| ERROR                        | 22     | 65.02914885     | 2.95587040    |
| CORRECTED TOTAL              | 32     | 1430.35758234   |               |
| MODEL F = 46.19              |        | PR > F = 0.0001 |               |
| R-SQUARE                     | C.V.   | ROOT MSE        | REC-PLNT MEAN |
| 0.954536                     | 8.8770 | 1.71926449      | 19.36770000   |
| SOURCE                       | DF     | TYPE IV SS      | PR > F        |
| TRT                          | 10     | 1365.32843349   | 0.0001        |
| CONTRAST                     | DF     | SS              | PR > F        |
| 1:G-VIRG VS CROPPED          | 1      | 12.76813818     | 0.0495        |
| 2:L-VIRG VS CROPPED          | 1      | 7.63045549      | 0.1224        |
| 3:G-VIRG VS NGPU             | 1      | 39.21671004     | 0.0015        |
| 4:L-VIRG VS NGPU             | 0      | NON-EST         |               |
| 5:G-CA1 VS CA2               | 1      | 0.05786574      | 0.8900        |
| 6:L-CA1 VS CA2               | 1      | 29.02034314     | 0.0048        |
| 7:G-CA1PO VS CA1P1           | 1      | 2.02943504      | 0.4162        |
| 8:L-CA1PO VS CA1P1           | 1      | 6.59863014      | 0.1494        |
| 9:G-CA2PO VS CA2P1           | 1      | 4.85964001      | 0.2131        |
| 10:L-CA2PO VS CA2P1          | 1      | 0.48229020      | 0.6902        |

Table A2.6-continued.

| DEPENDENT VARIABLE: |    | UNACC |                 |             |
|---------------------|----|-------|-----------------|-------------|
| SOURCE              | DF |       | SUM OF SQUARES  | MEAN SQUARE |
| MODEL               | 10 |       | 0.14184390      | 0.01418439  |
| ERROR               | 22 |       | 0.18465011      | 0.00839319  |
| CORRECTED TOTAL     | 32 |       | 0.32649401      |             |
| MODEL F = 1.69      |    |       | PR > F = 0.1464 |             |

|          |        |            |            |
|----------|--------|------------|------------|
| R-SQUARE | C.V.   | ROOT MSE   | UNACC MEAN |
| 0.434446 | 7.2216 | 0.09161434 | 1.26861259 |

|        |    |            |        |
|--------|----|------------|--------|
| SOURCE | DF | TYPE IV SS | PR > F |
| TRT    | 10 | 0.14184390 | 0.1464 |

|                     |    |            |        |
|---------------------|----|------------|--------|
| CONTRAST            | DF | SS         | PR > F |
| 1:G-VIRG VS CROPPED | 1  | 0.00003576 | 0.9485 |
| 2:L-VIRG VS CROPPED | 1  | 0.01286300 | 0.2288 |
| 3:G-VIRG VS NGPU    | 1  | 0.00977522 | 0.2922 |
| 4:L-VIRG VS NGPU    | 0  | NON-EST    |        |
| 5:G-CA1 VS CA2      | 1  | 0.00000076 | 0.9925 |
| 6:L-CA1 VS CA2      | 1  | 0.00295746 | 0.5588 |
| 7:G-CA1PO VS CA1P1  | 1  | 0.00726189 | 0.3624 |
| 8:L-CA1PO VS CA1P1  | 1  | 0.04058872 | 0.0387 |
| 9:G-CA2PO VS CA2P1  | 1  | 0.00024725 | 0.8653 |
| 10:L-CA2PO VS CA2P1 | 1  | 0.05986631 | 0.0140 |

Table A2.6-continued.

| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 11 | 0.00256228      | 0.00023293  |
| ERROR                        | 24 | 0.00010053      | 0.00000419  |
| CORRECTED TOTAL              | 35 | 0.00266281      |             |
| MODEL F = 55.61              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
|----------|--------|------------|---------------|
| 0.962245 | 1.7039 | 0.00204668 | 0.12011789    |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 11 | 0.00256228 | 0.0001 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 0.00017047 | 0.0001 |
| 2:L-VIRG VS CROPPED | 1  | 0.00017047 | 0.0001 |
| 3:G-VIRG VS NGPU    | 1  | 0.00092872 | 0.0001 |
| 4:L-VIRG VS NGPU    | 1  | 0.00092872 | 0.0001 |
| 5:G-CA1 VS CA2      | 1  | 0.00012370 | 0.0001 |
| 6:L-CA1 VS CA2      | 1  | 0.00012370 | 0.0001 |
| 7:G-CA1PO VS CA1P1  | 1  | 0.00000097 | 0.6353 |
| 8:L-CA1PO VS CA1P1  | 1  | 0.00000097 | 0.6353 |
| 9:G-CA2PO VS CA2P1  | 1  | 0.00016332 | 0.0001 |
| 10:L-CA2PO VS CA2P1 | 1  | 0.00016332 | 0.0001 |

| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 11 | 0.00107525      | 0.00009775  |
| ERROR                       | 24 | 0.00060039      | 0.00002502  |
| CORRECTED TOTAL             | 35 | 0.00167563      |             |
| MODEL F = 3.91              |    | PR > F = 0.0025 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-FIN MEAN |
|----------|--------|------------|--------------|
| 0.641697 | 4.1035 | 0.00500161 | 0.12188656   |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 11 | 0.00107525 | 0.0025 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 0.00005112 | 0.1657 |
| 2:L-VIRG VS CROPPED | 1  | 0.00003004 | 0.2840 |
| 3:G-VIRG VS NGPU    | 1  | 0.00039629 | 0.0006 |
| 4:L-VIRG VS NGPU    | 1  | 0.00017944 | 0.0131 |
| 5:G-CA1 VS CA2      | 1  | 0.00009136 | 0.0680 |
| 6:L-CA1 VS CA2      | 1  | 0.00002118 | 0.3667 |
| 7:G-CA1PO VS CA1P1  | 1  | 0.00001849 | 0.3984 |
| 8:L-CA1PO VS CA1P1  | 1  | 0.00001162 | 0.5020 |
| 9:G-CA2PO VS CA2P1  | 1  | 0.00007189 | 0.1030 |

Table A2.6-continued.

| DEPENDENT VARIABLE: CN-INIT |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 11 | 6.93876947      | 0.63079722  |
| ERROR                       | 12 | 2.97556527      | 0.21463044  |
| CORRECTED TOTAL             | 23 | 9.91433474      |             |
| MODEL F = 2.94              |    | PR > F = 0.0385 |             |

| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
|----------|--------|------------|--------------|
| 0.729296 | 4.5156 | 0.46328225 | 10.25964167  |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 11 | 6.93876947 | 0.0385 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 1.61953929 | 0.0177 |
| 2:L-VIRG VS CROPPED | 1  | 1.61953929 | 0.0177 |
| 3:G-VIRG VS NGPJ    | 1  | 0.74926336 | 0.0863 |
| 4:L-VIRG VS NGPU    | 1  | 0.74926336 | 0.0863 |
| 5:G-CA1 VS CA2      | 1  | 1.45427985 | 0.0231 |
| 6:L-CA1 VS CA2      | 1  | 1.45427985 | 0.0231 |
| 7:G-CA1PO VS CA1P1  | 1  | 0.33843306 | 0.2331 |
| 8:L-CA1PO VS CA1P1  | 1  | 0.33843306 | 0.2331 |
| 9:G-CA2PO VS CA2P1  | 1  | 0.05098564 | 0.6348 |
| 10:L-CA2PO VS CA2P1 | 1  | 0.05098564 | 0.6348 |

| DEPENDENT VARIABLE: CN-FIN |    |                 |             |
|----------------------------|----|-----------------|-------------|
| SOURCE                     | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                      | 11 | 3.42663487      | 0.31151226  |
| ERROR                      | 24 | 8.05175594      | 0.33548983  |
| CORRECTED TOTAL            | 35 | 11.47839081     |             |
| MODEL F = 0.93             |    | PR > F = 0.5306 |             |

| R-SQUARE | C.V.   | ROOT MSE   | CN-FIN MEAN |
|----------|--------|------------|-------------|
| 0.298529 | 5.2855 | 0.57921484 | 10.95861667 |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 11 | 3.42663487 | 0.5306 |

| CONTRAST            | DF | SS         | PR > F |
|---------------------|----|------------|--------|
| 1:G-VIRG VS CROPPED | 1  | 0.46816667 | 0.2491 |
| 2:L-VIRG VS CROPPED | 1  | 1.02181500 | 0.0937 |
| 3:G-VIRG VS NGPU    | 1  | 0.52788868 | 0.2218 |
| 4:L-VIRG VS NGPU    | 1  | 0.11634338 | 0.5614 |
| 5:G-CA1 VS CA2      | 1  | 0.00094696 | 0.9581 |
| 6:L-CA1 VS CA2      | 1  | 0.12921025 | 0.5407 |
| 7:G-CA1PO VS CA1P1  | 1  | 0.14698480 | 0.5143 |
| 8:L-CA1PO VS CA1P1  | 1  | 0.09385003 | 0.6017 |
| 9:G-CA2PO VS CA2P1  | 1  | 0.02080348 | 0.8055 |
| 10:L-CA2PO VS CA2P1 | 1  | 0.48712203 | 0.2400 |

Table A2.7 - Correlations for Virgin Soils.

| CORRELATIONS WITH BOTH RESIDUES COMBINED                |         |         |         |         |          |          |        |
|---------------------------------------------------------|---------|---------|---------|---------|----------|----------|--------|
| VARIABLE                                                | N       | MEAN    | STD DEV | SLM     | MINIMUM  | MAXIMUM  |        |
| TKN-FIN                                                 | 30      | 0.0869  | 0.02982 | 2.61    | 0.0453   | 0.1352   |        |
| CN-INIT                                                 | 20      | 11.5070 | 1.64457 | 230.14  | 9.1389   | 14.3594  |        |
| CN-FIN                                                  | 30      | 11.8827 | 2.04452 | 356.48  | 7.7488   | 18.1044  |        |
| DIFF-CN                                                 | 20      | 0.0398  | 1.61709 | 0.80    | -3.5884  | 2.7753   |        |
| REC-SOIL                                                | 30      | 56.9693 | 8.40024 | 1709.08 | 39.6430  | 75.5820  |        |
| REC-PLNT                                                | 27      | 16.7427 | 6.29537 | 452.05  | 0.3839   | 29.3648  |        |
| UNACC                                                   | 27      | 1.4069  | 0.15054 | 37.99   | 1.0329   | 1.6564   |        |
| RESIDUE                                                 | 30      | 1.5000  | 0.50855 | 45.00   | 1.0000   | 2.0000   |        |
| TKN-INIT                                                | 30      | 0.0838  | 0.03157 | 2.51    | 0.0399   | 0.1302   |        |
| CORRELATION COEFF./ PROB > :R: UNDER H0:RHO=0 /NO. OBS. |         |         |         |         |          |          |        |
|                                                         | TKN-FIN | CN-INIT | CN-FIN  | DIFF-CN | REC-SOIL | REC-PLNT | JNACC  |
| RESIDUE                                                 | 0.129   | 0.000   | -0.237  | -0.146  | -0.596   | 0.844    | -0.010 |
|                                                         | 0.50    | 1.00    | 0.21    | 0.54    | 0.01     | 0.01     | 0.96   |
|                                                         | 30      | 20      | 30      | 20      | 30       | 27       | 27     |
| TKN-INIT                                                | 0.946   | -0.702  | -0.047  | 0.843   | 0.349    | 0.201    | -0.611 |
|                                                         | 0.01    | 0.01    | 0.80    | 0.01    | 0.06     | 0.31     | 0.01   |
|                                                         | 30      | 20      | 30      | 20      | 30       | 27       | 27     |
| CN-INIT                                                 | -0.708  | 1.000   | 0.486   | -0.554  | -0.085   | -0.019   | 0.229  |
|                                                         | 0.01    | 0.00    | 0.03    | 0.01    | 0.72     | 0.94     | 0.36   |
|                                                         | 20      | 20      | 20      | 20      | 20       | 18       | 18     |
| CN-FIN                                                  | -0.273  | 0.486   | 1.000   | 0.458   | -0.240   | -0.110   | 0.290  |
|                                                         | 0.14    | 0.03    | 0.00    | 0.04    | 0.20     | 0.59     | 0.14   |
|                                                         | 30      | 20      | 30      | 20      | 30       | 27       | 27     |
| DIFF-CN                                                 | 0.731   | -0.554  | 0.458   | 1.000   | 0.094    | -0.001   | -0.237 |
|                                                         | 0.01    | 0.01    | 0.04    | 0.00    | 0.69     | 0.99     | 0.34   |
|                                                         | 20      | 20      | 20      | 20      | 20       | 18       | 18     |
| REC-SOIL                                                | 0.436   | -0.085  | -0.240  | 0.094   | 1.000    | -0.359   | -0.717 |
|                                                         | 0.02    | 0.72    | 0.20    | 0.69    | 0.00     | 0.07     | 0.01   |
|                                                         | 30      | 20      | 30      | 20      | 30       | 27       | 27     |
| REC-PLNT                                                | 0.334   | -0.019  | -0.111  | -0.001  | -0.359   | 1.000    | -0.364 |
|                                                         | 0.09    | 0.94    | 0.59    | 0.99    | 0.07     | 0.00     | 0.06   |
|                                                         | 27      | 18      | 27      | 18      | 27       | 27       | 27     |
| UNACC                                                   | -0.789  | 0.229   | 0.290   | -0.237  | -0.717   | -0.364   | 1.000  |
|                                                         | 0.01    | 0.36    | 0.14    | 0.34    | 0.01     | 0.06     | 0.00   |
|                                                         | 27      | 18      | 27      | 18      | 27       | 27       | 27     |

Table A2.7-continued.

RESIDUE = 1 = GRASS

| VARIABLE | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|---------|---------|---------|---------|
| TKN-FIN  | 12 | 0.0767  | 0.03135 | 0.920   | 0.0453  | 0.1292  |
| CN-INIT  | 8  | 11.8062 | 1.76796 | 94.450  | 9.1389  | 14.3594 |
| CN-FIN   | 12 | 12.7220 | 2.63093 | 152.664 | 9.8911  | 18.1044 |
| DIFF-CN  | 8  | 0.1043  | 1.63948 | 0.834   | -1.7329 | 2.7753  |
| REC-SOIL | 12 | 60.2832 | 8.05107 | 723.399 | 46.8720 | 75.5820 |
| REC-PLNT | 12 | 12.3538 | 2.94803 | 148.246 | 6.3839  | 16.3086 |
| UNACC    | 12 | 1.4265  | 0.16442 | 17.118  | 1.1308  | 1.6247  |
| TKN-INIT | 12 | 0.0785  | 0.03405 | 0.942   | 0.0399  | 0.1302  |

CORRELATION COEFF./ PROB &gt; :R: UNDER H0:RHO=0 /NO. OBS.

|          | TKN-FIN              | CN-INIT             | CN-FIN               | DIFF-CN             | REC-SOIL             | REC-PLNT             | UNACC                |
|----------|----------------------|---------------------|----------------------|---------------------|----------------------|----------------------|----------------------|
| TKN-INIT | 0.951<br>0.01<br>12  | -0.658<br>0.08<br>8 | -0.024<br>0.94<br>12 | 0.809<br>0.02<br>8  | 0.354<br>0.26<br>12  | 0.919<br>0.01<br>12  | -0.563<br>0.06<br>12 |
| CN-INIT  | -0.630<br>0.09<br>8  | 1.000<br>0.00<br>8  | 0.504<br>0.20<br>8   | -0.622<br>0.10<br>8 | 0.167<br>0.69<br>8   | -0.619<br>0.10<br>8  | -0.017<br>0.97<br>8  |
| CN-FIN   | -0.273<br>0.39<br>12 | 0.504<br>0.20<br>8  | 1.000<br>0.00<br>12  | 0.363<br>0.38<br>8  | -0.504<br>0.09<br>12 | 0.073<br>0.82<br>12  | 0.358<br>0.25<br>12  |
| DIFF-CN  | 0.722<br>0.04<br>8   | -0.622<br>0.10<br>8 | 0.363<br>0.38<br>8   | 1.000<br>0.00<br>8  | -0.068<br>0.87<br>8  | 0.719<br>0.04<br>8   | -0.103<br>0.81<br>8  |
| REC-SOIL | 0.596<br>0.04<br>12  | 0.167<br>0.69<br>8  | -0.504<br>0.09<br>12 | -0.068<br>0.87<br>8 | 1.000<br>0.00<br>12  | 0.379<br>0.23<br>12  | -0.955<br>0.01<br>12 |
| REC-PLNT | 0.867<br>0.01<br>12  | -0.619<br>0.10<br>8 | 0.073<br>0.82<br>12  | 0.719<br>0.04<br>8  | 0.379<br>0.23<br>12  | 1.000<br>0.00<br>12  | -0.598<br>0.04<br>12 |
| UNACC    | -0.747<br>0.01<br>12 | -0.017<br>0.97<br>8 | 0.358<br>0.25<br>12  | -0.103<br>0.81<br>8 | -0.955<br>0.01<br>12 | -0.598<br>0.04<br>12 | 1.000<br>0.00<br>12  |

Table A2.7-continued.

## RESIDUE = 2 = LEGUME

| VARIABLE | N  | MEAN    | STD DEV | SUM     | MINIMUM | MAXIMUM |
|----------|----|---------|---------|---------|---------|---------|
| TKN-FIN  | 12 | 0.0840  | 0.02891 | 1.008   | 0.0466  | 0.1352  |
| CN-INIT  | 8  | 11.8062 | 1.76796 | 94.450  | 9.1389  | 14.3594 |
| CN-FIN   | 12 | 11.5047 | 1.62284 | 138.056 | 7.7488  | 13.8279 |
| DIFF-CN  | 8  | -0.4074 | 1.91698 | -3.259  | -3.5885 | 2.3281  |
| REC-SOIL | 12 | 50.9697 | 5.52533 | 611.636 | 39.6430 | 57.8460 |
| REC-PLNT | 9  | 20.8987 | 3.29425 | 188.088 | 16.0296 | 24.9342 |
| UNACC    | 9  | 1.4691  | 0.09516 | 13.222  | 1.3653  | 1.6564  |
| TKN-INIT | 12 | 0.0785  | 0.03405 | 0.942   | 0.0399  | 0.1302  |

CORRELATION COEFF./ PROB &gt; |R| UNDER H0:RHO=0 / NO. OBS.

|          | TKN-FIN             | CN-INIT             | CN-FIN               | DIFF-CN             | REC-SOIL             | REC-PLNT            | UNACC                |
|----------|---------------------|---------------------|----------------------|---------------------|----------------------|---------------------|----------------------|
| TKN-INIT | 0.976<br>0.01<br>12 | -0.658<br>0.08<br>8 | 0.129<br>0.69<br>12  | 0.894<br>0.01<br>8  | 0.374<br>0.23<br>12  | 0.392<br>0.30<br>9  | -0.334<br>0.38<br>11 |
| CN-INIT  | -0.214<br>0.57<br>8 | -0.716<br>0.00<br>8 | 1.000<br>0.21<br>8   | 0.482<br>0.29<br>8  | -0.425<br>0.54<br>8  | -0.257<br>0.15<br>6 | -0.214<br>0.68<br>6  |
| CN-FIN   | 0.019<br>0.95<br>12 | 0.484<br>0.23<br>8  | 12.000<br>0.00<br>12 | 0.589<br>0.12<br>8  | -0.277<br>0.38<br>12 | 0.463<br>0.21<br>9  | -0.070<br>0.86<br>9  |
| DIFF-CN  | 0.830<br>0.01<br>8  | -0.425<br>0.29<br>8 | 0.589<br>0.12<br>8   | 1.000<br>0.00<br>8  | -0.164<br>0.70<br>8  | 0.538<br>0.27<br>6  | 0.006<br>0.99<br>6   |
| REC-SOIL | 0.541<br>0.07<br>12 | 0.257<br>0.54<br>8  | -0.277<br>0.38<br>12 | -0.164<br>0.70<br>8 | 1.000<br>0.00<br>12  | 0.246<br>0.52<br>9  | -0.902<br>0.01<br>9  |
| REC-PLNT | 0.402<br>0.28<br>9  | 0.666<br>0.15<br>6  | 0.463<br>0.21<br>9   | 0.538<br>0.27<br>6  | 0.246<br>0.52<br>9   | 1.000<br>0.00<br>9  | -0.628<br>0.07<br>9  |
| UNACC    | -0.669<br>0.05<br>9 | -0.214<br>0.68<br>6 | -0.070<br>0.86<br>9  | 0.006<br>0.99<br>6  | -0.902<br>0.01<br>9  | -0.628<br>0.07<br>9 | 1.000<br>0.00<br>9   |

Table A2.8 - Analysis of variance for Virgin soils.

| DEPENDENT VARIABLE: REC-SOIL |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 11 | 1174.37487996   | 106.76135272 |
| ERROR                        | 12 | 394.92150400    | 32.91012533  |
| CORRECTED TOTAL              | 23 | 1569.29638396   |              |
| MODEL F = 3.24               |    | PR > F = 0.0272 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-SOIL MEAN |
|----------|---------|------------|---------------|
| 0.748345 | 10.3130 | 5.73673473 | 55.62645833   |

| SOURCE             | DF | TYPE IV SS   | PR > F |
|--------------------|----|--------------|--------|
| REP                | 2  | 105.60973908 | 0.2413 |
| RESIDUE            | 1  | 520.45700704 | 0.0018 |
| REP*RESIDUE        | 2  | 196.95049158 | 0.0882 |
| MANAGEMENT         | 3  | 297.20549079 | 0.0722 |
| MANAGEMENT*RESIDUE | 3  | 54.15215146  | 0.6586 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS   | PR > F |
|---------|----|--------------|--------|
| RESIDUE | 1  | 520.45700704 | 0.1483 |

| DEPENDENT VARIABLE: REC-PLNT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 10 | 491.94948325    | 49.19595833 |
| ERROR                        | 10 | 65.96194974     | 6.59619497  |
| CORRECTED TOTAL              | 20 | 557.92153300    |             |
| MODEL F = 7.46               |    | PR > F = 0.0019 |             |

| R-SQUARE | C.V.    | ROOT MSE   | REC-PLNT MEAN |
|----------|---------|------------|---------------|
| 0.881772 | 16.0360 | 2.56830586 | 16.01859048   |

| SOURCE             | DF | TYPE I SS    | PR > F |
|--------------------|----|--------------|--------|
| REP                | 2  | 2.11891731   | 0.8538 |
| RESIDUE            | 1  | 375.50538636 | 0.0001 |
| REP*RESIDUE        | 2  | 1.11503648   | 0.9196 |
| MANAGEMENT         | 3  | 104.22616336 | 0.0195 |
| MANAGEMENT*RESIDUE | 2  | 8.99407974   | 0.5278 |

| SOURCE             | DF | TYPE IV SS   | PR > F |
|--------------------|----|--------------|--------|
| REP                | 2  | 2.28231756   | 0.8436 |
| RESIDUE            | 1* | 431.11539643 | 0.0001 |
| REP*RESIDUE        | 2  | 1.11503648   | 0.9196 |
| MANAGEMENT         | 3* | 93.36024300  | 0.0266 |
| MANAGEMENT*RESIDUE | 2  | 8.99407974   | 0.5278 |

\* NOTE. OTHER TYPE IV TESTABLE HYPOTHESES EXIST WHICH MAY YIELD DIFFERENCE SS.

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

| SOURCE  | DF | TYPE IV SS   | PR > F |
|---------|----|--------------|--------|
| RESIDUE | 1* | 431.11539643 | 0.0013 |

Table A2.8-continued.

|                     |       |                 |             |
|---------------------|-------|-----------------|-------------|
| DEPENDENT VARIABLE: | UNACC |                 |             |
| SOURCE              | DF    | SUM OF SQUARES  | MEAN SQUARE |
| MODEL               | 10    | 0.25863924      | 0.02586392  |
| ERROR               | 10    | 0.12049841      | 0.01204984  |
| CORRECTED TOTAL     | 20    | 0.37913765      |             |
| MODEL F = 2.15      |       | PR > F = 0.1221 |             |

|          |        |            |            |
|----------|--------|------------|------------|
| R-SQUARE | C.V.   | ROOT MSE   | UNACC MEAN |
| 0.682178 | 7.5981 | 0.10977177 | 1.44473037 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE I SS  | PR > F |
| REP                | 2  | 0.02840490 | 0.3470 |
| RESIDUE            | 1  | 0.00934147 | 0.3993 |
| REP*RESIDUE        | 2  | 0.04364138 | 0.2132 |
| MANAGEMENT         | 3  | 0.17457704 | 0.0249 |
| MANAGEMENT*RESIDUE | 2  | 0.00267445 | 0.8960 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 2  | 0.02499274 | 0.3897 |
| RESIDUE            | 1* | 0.00098064 | 0.7813 |
| REP*RESIDUE        | 2  | 0.04364138 | 0.2132 |
| MANAGEMENT         | 5* | 0.14672696 | 0.0398 |
| MANAGEMENT*RESIDUE | 4  | 0.00267445 | 0.8960 |

\* NOTE: OTHER TYPE IV TESTABLE HYPOTHESES EXIST WHICH MAY  
YIELD DIFFERENCE SS.

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS  
AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1* | 0.00098064 | 0.8518 |

Table A2.8-continued.

|                              |    |                 |             |
|------------------------------|----|-----------------|-------------|
| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 11 | 0.02547425      | 0.00231584  |
| ERROR                        | 12 | 0.00002856      | 0.00000258  |
| CORRECTED TOTAL              | 23 | 0.02550281      |             |
| MODEL F = 973.00             |    | PR > F = 0.0001 |             |

|          |        |            |               |
|----------|--------|------------|---------------|
| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
| 0.998880 | 1.9656 | 0.00154276 | 0.07848600    |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 2  | 0.00004969 | 0.0024 |
| RESIDJE            | 1  | 0.00000000 | 1.0000 |
| REP*RESIDUE        | 2  | 0.00000000 | 1.0000 |
| MANAGEMENT         | 3  | 0.02542456 | 0.0001 |
| MANAGEMENT*RESIDUE | 3  | 0.00000000 | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 0.00000000 |        |

|                             |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 11 | 0.01977338      | 0.00179758  |
| ERROR                       | 12 | 0.00055483      | 0.00004624  |
| CORRECTED TOTAL             | 23 | 0.02032821      |             |
| MODEL F = 38.88             |    | PR > F = 0.0001 |             |

|          |        |            |              |
|----------|--------|------------|--------------|
| R-SQUARE | C.V.   | ROOT MSE   | TKN-FIN MEAN |
| 0.972707 | 8.4619 | 0.00679968 | 0.08035654   |

|                    |    |            |        |
|--------------------|----|------------|--------|
| SOURCE             | DF | TYPE IV SS | PR > F |
| REP                | 2  | 0.00013797 | 0.2658 |
| RESIDUE            | 1  | 0.00032332 | 0.0214 |
| REP*RESIDUE        | 2  | 0.00029998 | 0.0748 |
| MANAGEMENT         | 3  | 0.01895522 | 0.0001 |
| MANAGEMENT*RESIDUE | 3  | 0.00005690 | 0.7486 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 0.00032332 | 0.2798 |

Table A2.8-continued.

|                             |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| DEPENDENT VARIABLE: CN-INIT |    |                 |             |
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 9  | 43.01678647     | 4.77964294  |
| ERROR                       | 6  | 0.74262093      | 0.12377016  |
| CORRECTED TOTAL             | 15 | 43.75940740     |             |
| MODEL F = 38.62             |    | PR > F = 0.0001 |             |

|          |        |            |              |
|----------|--------|------------|--------------|
| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
| 0.983029 | 2.9799 | 0.35180983 | 11.80620000  |

|                    |    |             |        |
|--------------------|----|-------------|--------|
| SOURCE             | DF | TYPE IV SS  | PR > F |
| REP                | 1  | 0.44957025  | 0.1053 |
| RESIDUE            | 1  | 0.00000000  | 1.0000 |
| REP*RESIDUE        | 1  | 0.00000000  | 1.0000 |
| MANAGEMENT         | 3  | 42.56721622 | 0.0001 |
| MANAGEMENT*RESIDUE | 3  | 0.00000000  | 1.0000 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 0.00000000 |        |

|                            |    |                 |             |
|----------------------------|----|-----------------|-------------|
| DEPENDENT VARIABLE: CN-FIN |    |                 |             |
| SOURCE                     | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                      | 11 | 87.14570518     | 7.92233583  |
| ERROR                      | 12 | 26.85555276     | 2.23796273  |
| CORRECTED TOTAL            | 23 | 114.00125794    |             |
| MODEL F = 3.54             |    | PR > F = 0.0198 |             |

|          |         |            |             |
|----------|---------|------------|-------------|
| R-SQUARE | C.V.    | ROOT MSE   | CN-FIN MEAN |
| 0.764428 | 12.3499 | 1.49598220 | 12.11335833 |

|                    |    |             |        |
|--------------------|----|-------------|--------|
| SOURCE             | DF | TYPE IV SS  | PR > F |
| REP                | 2  | 10.12188334 | 0.1468 |
| RESIDUE            | 1  | 8.89188961  | 0.0695 |
| REP*RESIDUE        | 2  | 8.77167096  | 0.1834 |
| MANAGEMENT         | 3  | 55.65138830 | 0.0030 |
| MANAGEMENT*RESIDUE | 3  | 3.70887297  | 0.6562 |

TESTS OF HYPOTHESES USING THE TYPE IV MS FOR REP\*RESIDUE AS AN ERROR TERM

|         |    |            |        |
|---------|----|------------|--------|
| SOURCE  | DF | TYPE IV SS | PR > F |
| RESIDUE | 1  | 8.89188961 | 0.2905 |

---

Table A2.9 - One degree of freedom contrasts for Virgin soils.

| DEPENDENT VARIABLE: REC-SOIL |    |                 |              |
|------------------------------|----|-----------------|--------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE  |
| MODEL                        | 7  | 871.81464929    | 124.54494990 |
| ERROR                        | 16 | 697.48173467    | 43.59260842  |
| CORRECTED TOTAL              | 23 | 1569.29638396   |              |
| MODEL F = 2.86               |    | PR > F = 0.0389 |              |

| R-SQUARE | C.V.    | ROOT MSE   | REC-SOIL MEAN |
|----------|---------|------------|---------------|
| 0.555545 | 11.8693 | 6.60246987 | 55.62645833   |

| SOURCE | DF | TYPE IV SS   | PR > F |
|--------|----|--------------|--------|
| TRT    | 7  | 871.81464929 | 0.0389 |

| CONTRAST           | DF | SS           | PR > F |
|--------------------|----|--------------|--------|
| 1:G-LA VS LE       | 1  | 248.00510417 | 0.0298 |
| 2:L-LA VS LE       | 1  | 30.74059350  | 0.4134 |
| 3:G-DT VS TR       | 1  | 32.58272067  | 0.4001 |
| 4:L-DT VS TR       | 1  | 34.05783750  | 0.3898 |
| 5:G-LA&LE VS DT&TR | 1  | 0.13889008   | 0.9557 |
| 6:L-LA&LE VS DT&TR | 1  | 5.83249633   | 0.7193 |
| 7:G-LA VS L-LA     | 1  | 31.16760417  | 0.4103 |

| DEPENDENT VARIABLE: REC-PLNT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 6  | 488.72562946    | 81.45427158 |
| ERROR                        | 14 | 69.19590353     | 4.94256454  |
| CORRECTED TOTAL              | 20 | 557.92153300    |             |
| MODEL F = 16.48              |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.    | ROOT MSE   | REC-PLNT MEAN |
|----------|---------|------------|---------------|
| 0.875976 | 13.9811 | 2.22318792 | 16.01589048   |

| SOURCE | DF | TYPE IV SS   | PR > F |
|--------|----|--------------|--------|
| TRT    | 6  | 488.72562946 | 0.0001 |

| CONTRAST           | DF | SS          | PR > F |
|--------------------|----|-------------|--------|
| 1:G-LA VS LE       | 1  | 12.40735160 | 0.1354 |
| 2:L-LA VS LE       | 1  | 3.87592363  | 0.3908 |
| 3:G-DT VS TR       | 1  | 9.97041504  | 0.1774 |
| 4:L-DT VS TR       | 0  | NON-EST     |        |
| 5:G-LA&LE VS DT&TR | 1  | 62.99058696 | 0.0031 |
| 6:L-LA&LE VS DT&TR | 0  | NON-EST     |        |
| 7:G-LA VS L-LA     | 1  | 97.01466704 | 0.0006 |

Table A2.9-continued.

|                     |       |                 |             |
|---------------------|-------|-----------------|-------------|
| DEPENDENT VARIABLE: | UNACC |                 |             |
| SOURCE              | DF    | SUM OF SQUARES  | MEAN SQUARE |
| MODEL               | 6     | 0.18659296      | 0.03109885  |
| ERROR               | 14    | 0.19254469      | 0.01375319  |
| CORRECTED TOTAL     | 20    | 0.37913766      |             |
| MODEL F = 2.26      |       | PR > F = 0.0978 |             |

|          |        |            |            |
|----------|--------|------------|------------|
| R-SQUARE | C.V.   | ROOT MSE   | UNACC MEAN |
| 0.492151 | 8.1174 | 0.11727401 | 1.44473037 |

|        |    |            |        |
|--------|----|------------|--------|
| SOURCE | DF | TYPE IV SS | PR > F |
| TRT    | 6  | 0.18659296 | 0.0978 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| CONTRAST           | DF | SS         | PR > F |
| 1:G-LA VS LE       | 1  | 0.11050380 | 0.0132 |
| 2:L-LA VS LE       | 1  | 0.00819030 | 0.4531 |
| 3:G-DT VS TR       | 1  | 0.02784515 | 0.1767 |
| 4:L-DT VS TR       | 0  | NON-EST    |        |
| 5:G-LA&LE VS DT&TR | 1  | 0.01592882 | 0.3000 |
| 6:L-LA&LE VS DT&TR | 0  | NON-EST    |        |
| 7:G-LA VS L-LA     | 1  | 0.00350940 | 0.6213 |

Table A2.9-continued.

| DEPENDENT VARIABLE: TKN-INIT |    |                 |             |
|------------------------------|----|-----------------|-------------|
| SOURCE                       | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                        | 7  | 0.02542456      | 0.00363208  |
| ERROR                        | 16 | 0.00007826      | 0.00000489  |
| CORRECTED TOTAL              | 23 | 0.02550281      |             |
| MODEL F = 742.60             |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-INIT MEAN |
|----------|--------|------------|---------------|
| 0.996951 | 2.8176 | 0.00221156 | 0.07848600    |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 7  | 0.02542456 | 0.0001 |

| CONTRAST           | DF | SS         | PR > F |
|--------------------|----|------------|--------|
| 1:G-LA VS LE       | 1  | 0.00389681 | 0.0001 |
| 2:L-LA VS LE       | 1  | 0.00389681 | 0.0001 |
| 3:G-DT VS TR       | 1  | 0.00075767 | 0.0001 |
| 4:L-DT VS TR       | 1  | 0.00075767 | 0.0001 |
| 5:G-LA&LE VS DT&TR | 1  | 0.00805780 | 0.0001 |
| 6:L-LA&LE VS DT&TR | 1  | 0.00805780 | 0.0001 |
| 7:G-LA VS L-LA     | 1  | 0.00000000 | 1.0000 |

| DEPENDENT VARIABLE: TKN-FIN |    |                 |             |
|-----------------------------|----|-----------------|-------------|
| SOURCE                      | DF | SUM OF SQUARES  | MEAN SQUARE |
| MODEL                       | 7  | 0.01933543      | 0.00276220  |
| ERROR                       | 16 | 0.00099277      | 0.00006205  |
| CORRECTED TOTAL             | 23 | 0.02032821      |             |
| MODEL F = 44.52             |    | PR > F = 0.0001 |             |

| R-SQUARE | C.V.   | ROOT MSE   | TKN-FIN MEAN |
|----------|--------|------------|--------------|
| 0.951163 | 9.8027 | 0.00787708 | 0.08035654   |

| SOURCE | DF | TYPE IV SS | PR > F |
|--------|----|------------|--------|
| TRT    | 7  | 0.01933543 | 0.0001 |

| CONTRAST           | DF | SS         | PR > F |
|--------------------|----|------------|--------|
| 1:G-LA VS LE       | 1  | 0.00452947 | 0.0001 |
| 2:L-LA VS LE       | 1  | 0.00384616 | 0.0001 |
| 3:G-DT VS TR       | 1  | 0.00032631 | 0.0357 |
| 4:L-DT VS TR       | 1  | 0.00057217 | 0.0357 |
| 5:G-LA&LE VS DT&TR | 1  | 0.00536948 | 0.0001 |
| 6:L-LA&LE VS DT&TR | 1  | 0.00436852 | 0.0001 |
| 7:G-LA VS L-LA     | 1  | 0.00008269 | 0.2653 |

Table A2.9-continued.

|                     |         |                 |             |
|---------------------|---------|-----------------|-------------|
| DEPENDENT VARIABLE: | CN-INIT |                 |             |
| SOURCE              | DF      | SUM OF SQUARES  | MEAN SQUARE |
| MODEL               | 7       | 42.56721622     | 6.08103089  |
| ERROR               | 8       | 1.19219118      | 0.14902390  |
| CORRECTED TOTAL     | 15      | 43.75940740     |             |
| MODEL F = 40.81     |         | PR > F = 0.0001 |             |

|          |        |            |              |
|----------|--------|------------|--------------|
| R-SQUARE | C.V.   | ROOT MSE   | CN-INIT MEAN |
| 0.972756 | 3.2698 | 0.38603613 | 11.80620000  |

|        |    |             |        |
|--------|----|-------------|--------|
| SOURCE | DF | TYPE IV SS  | PR > F |
| TRT    | 7  | 42.56721622 | 0.0001 |

|                    |    |            |        |
|--------------------|----|------------|--------|
| CONTRAST           | DF | SS         | PR > F |
| 1:G-LA VS LE       | 1  | 8.79715600 | 0.0001 |
| 2:L-LA VS LE       | 1  | 8.79715600 | 0.0001 |
| 3:G-DT VS TR       | 1  | 6.31165129 | 0.0002 |
| 4:L-DT VS TR       | 1  | 6.31165129 | 0.0002 |
| 5:G-LA&LE VS DT&TR | 1  | 6.17480082 | 0.0002 |
| 6:L-LA&LE VS DT&TR | 1  | 6.17480082 | 0.0002 |
| 7:G-LA VS L-LA     | 1  | 0.00000000 | 1.0000 |

|                     |        |                 |             |
|---------------------|--------|-----------------|-------------|
| DEPENDENT VARIABLE: | CN-FIN |                 |             |
| SOURCE              | DF     | SUM OF SQUARES  | MEAN SQUARE |
| MODEL               | 7      | 68.25215088     | 9.75030727  |
| ERROR               | 16     | 45.74910706     | 2.85931919  |
| CORRECTED TOTAL     | 23     | 114.00125794    |             |
| MODEL F = 3.41      |        | PR > F = 0.0200 |             |

|          |         |            |             |
|----------|---------|------------|-------------|
| R-SQUARE | C.V.    | ROOT MSE   | CN-FIN MEAN |
| 0.598696 | 13.9594 | 1.69095216 | 12.11335833 |

|        |    |             |        |
|--------|----|-------------|--------|
| SOURCE | DF | TYPE IV SS  | PR > F |
| TRT    | 7  | 68.25215088 | 0.0200 |

|                    |    |             |        |
|--------------------|----|-------------|--------|
| CONTRAST           | DF | SS          | PR > F |
| 1:G-LA VS LE       | 1  | 7.18689496  | 0.1324 |
| 2:L-LA VS LE       | 1  | 0.25305281  | 0.7699 |
| 3:G-DT VS TR       | 1  | 33.78060448 | 0.0034 |
| 4:L-DT VS TR       | 1  | 17.93560862 | 0.0235 |
| 5:G-LA&LE VS DT&TR | 1  | 0.20178727  | 0.7939 |
| 6:L-LA&LE VS DT&TR | 1  | 0.00031314  | 0.9918 |
| 7:G-LA VS L-LA     | 1  | 5.89268420  | 0.1704 |

Table A2.10 - Tests between initial and final TKN and C:N ratio.

| RESIDUE      | VARIABLE | MEAN        | STD ERROR<br>OF MEAN | T     | PR> T  |
|--------------|----------|-------------|----------------------|-------|--------|
| LA SOIL      |          |             |                      |       |        |
| GRASS        | DIFF-TKN | -0.00261392 | 0.00298110           | -0.88 | 0.3993 |
|              | DIFF-CN  | 0.39628750  | 0.39340546           | 1.01  | 0.3473 |
| LEGUME       | DIFF-TKN | -0.00178517 | 0.00614522           | -0.29 | 0.7768 |
|              | DIFF-CN  | 1.28321250  | 1.64406638           | 0.78  | 0.4607 |
| LE SOIL      |          |             |                      |       |        |
| GRASS        | DIFF-TKN | -0.00058872 | 0.00113135           | -0.52 | 0.6095 |
|              | DIFF-CN  | 0.93269167  | 0.24393768           | 3.82  | 0.0028 |
| LEGUME       | DIFF-TKN | 0.00412606  | 0.00199804           | 2.07  | 0.0545 |
|              | DIFF-CN  | 0.64020833  | 0.33031838           | 1.94  | 0.0787 |
| ULTISOLS     |          |             |                      |       |        |
| GRASS        | DIFF-TKN | 0.00296000  | 0.00449300           | 0.66  | 0.5391 |
|              | DIFF-CN  | -0.63457500 | 0.73135347           | -0.87 | 0.4494 |
| LEGUME       | DIFF-TKN | 0.01237400  | 0.00263915           | 4.69  | 0.0054 |
|              | DIFF-CN  | -1.44155000 | 0.82863189           | -1.74 | 0.1803 |
| VIRGIN SOILS |          |             |                      |       |        |
| GRASS        | DIFF-TKN | -0.00062787 | 0.00264474           | -0.24 | 0.8158 |
|              | DIFF-CN  | 0.26938000  | 0.47585745           | 0.57  | 0.5852 |
| LEGUME       | DIFF-TKN | 0.00693013  | 0.00232157           | 2.99  | 0.0098 |
|              | DIFF-CN  | -0.18975000 | 0.56026609           | -0.34 | 0.7426 |

APPENDIX 3  
CARBON DIOXIDE EVOLUTION ANALYSES

Table A3.1 - Analysis of variance for CO<sub>2</sub> evolution.

LA-Acrustox Soil

DEPENDENT VARIABLE: C-30

| SOURCE      | DF | SS     | MS    | F VALUE  | PR > F | R-SQUARE  | C.V. |
|-------------|----|--------|-------|----------|--------|-----------|------|
| MODEL       | 4  | 387.31 | 96.83 | 70.49    | 0.0027 | 0.99      | 2.81 |
| ERROR       | 3  | 4.12   | 1.37  | ROOT MSE |        | C-30 MEAN |      |
| CORR. TOTAL | 7  | 391.43 |       | 1.17     |        | 41.77     |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 165.62   | 120.57  | 0.0016 |
| MANAGEMENT | 3  | 221.69   | 53.80   | 0.0042 |

DEPENDENT VARIABLE: C-100

| SOURCE      | DF | SS     | MS     | F VALUE  | PR > F | R-SQUARE   | C.V. |
|-------------|----|--------|--------|----------|--------|------------|------|
| MODEL       | 4  | 675.86 | 168.97 | 52.59    | 0.0041 | 0.99       | 3.38 |
| ERROR       | 3  | 9.64   | 3.21   | ROOT MSE |        | C-100 MEAN |      |
| CORR. TOTAL | 7  | 391.43 |        | 1.79     |        | 52.99      |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 274.72   | 85.81   | 0.0027 |
| MANAGEMENT | 3  | 401.15   | 41.62   | 0.0061 |

Table A3.1-continued.

LE-Haplustox Soil

DEPENDENT VARIABLE: C-30

| SOURCE      | DF | SS      | MS     | F VALUE  | PR > F | R-SQUARE  | C.V. |
|-------------|----|---------|--------|----------|--------|-----------|------|
| MODEL       | 6  | 1129.55 | 188.26 | 49.48    | 0.0003 | 0.98      | 5.16 |
| ERROR       | 5  | 19.02   | 3.80   | ROOT MSE |        | C-30 MEAN |      |
| CORR. TOTAL | 11 | 1148.57 |        | 1.95     |        | 37.81     |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 219.14   | 57.59   | 0.0006 |
| MANAGEMENT | 5  | 910.41   | 47.86   | 0.0003 |

DEPENDENT VARIABLE: C-100

| SOURCE      | DF | SS      | MS     | F VALUE  | PR > F | R-SQUARE   | C.V. |
|-------------|----|---------|--------|----------|--------|------------|------|
| MODEL       | 6  | 1631.85 | 271.97 | 34.60    | 0.0006 | 0.98       | 5.63 |
| ERROR       | 5  | 39.30   | 7.86   | ROOT MSE |        | C-100 MEAN |      |
| CORR. TOTAL | 11 | 1671.15 |        | 2.80     |        | 49.83      |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 158.85   | 20.21   | 0.0064 |
| MANAGEMENT | 5  | 1473.00  | 37.48   | 0.0006 |

Virgin Soils

DEPENDENT VARIABLE: C-30

| SOURCE      | DF | SS     | MS    | F VALUE  | PR > F | R-SQUARE  | C.V. |
|-------------|----|--------|-------|----------|--------|-----------|------|
| MODEL       | 4  | 398.79 | 99.70 | 7.97     | 0.0508 | 0.91      | 7.38 |
| ERROR       | 3  | 38.00  | 12.67 | ROOT MSE |        | C-30 MEAN |      |
| CORR. TOTAL | 7  | 436.79 |       | 3.56     |        | 48.25     |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 120.13   | 9.48    | 0.0542 |
| MANAGEMENT | 3  | 278.67   | 7.33    | 0.0650 |

DEPENDENT VARIABLE: C-100

| SOURCE      | DF | SS     | MS     | F VALUE  | PR > F | R-SQUARE   | C.V. |
|-------------|----|--------|--------|----------|--------|------------|------|
| MODEL       | 4  | 422.13 | 105.53 | 8.99     | 0.510  | 0.92       | 5.51 |
| ERROR       | 3  | 35.23  | 11.74  | ROOT MSE |        | C-100 MEAN |      |
| CORR. TOTAL | 7  | 437.36 |        | 3.43     |        | 62.14      |      |

| SOURCE     | DF | ANOVA SS | F VALUE | PR > F |
|------------|----|----------|---------|--------|
| REP        | 1  | 131.67   | 11.23   | 0.0440 |
| MANAGEMENT | 3  | 290.26   | 8.24    | 0.0585 |

Table 3.2 - One degree of freedom contrasts for CO<sub>2</sub> evolution.LA-Acrustox Soil

DEPENDENT VARIABLE: C-30

| CONTRAST          | DF | SS     | F VALUE | PR > F |
|-------------------|----|--------|---------|--------|
| 1:VIRG VS CROPPED | 1  | 186.60 | 4.40    | 0.1040 |
| 2:LOW1 VS HIGH2&3 | 1  | 34.41  | 0.81    | 0.4186 |
| 3:HIGH2 HIGH3     | 1  | 0.69   | 0.02    | 0.9048 |

DEPENDENT VARIABLE: C-100

| CONTRAST          | DF | SS     | F VALUE | PR > F |
|-------------------|----|--------|---------|--------|
| 1:VIRG VS CROPPED | 1  | 315.09 | 4.43    | 0.1030 |
| 2:LOW1 VS HIGH2&3 | 1  | 85.92  | 1.21    | 0.3333 |
| 3:HIGH2 HIGH3     | 1  | 0.16   | 0.00    | 0.9649 |

LE-Haplustox Soil

DEPENDENT VARIABLE: C-30

| CONTRAST          | DF | SS     | F VALUE | PR > F |
|-------------------|----|--------|---------|--------|
| 1:VIRG VS CROPPED | 1  | 579.20 | 14.59   | 0.0088 |
| 2:VIRG VS NGPU    | 1  | 673.14 | 16.96   | 0.0062 |
| 3:CA1 VS CA2      | 1  | 8.84   | 0.22    | 0.6336 |
| 4:CA1PO VS CA1P1  | 1  | 67.82  | 1.71    | 0.2390 |
| 5:CA2PO VS CA2P1  | 1  | 62.88  | 1.58    | 0.2549 |

DEPENDENT VARIABLE: C-100

| CONTRAST          | DF | SS     | F VALUE | PR > F |
|-------------------|----|--------|---------|--------|
| 1:VIRG VS CROPPED | 1  | 868.16 | 26.29   | 0.0022 |
| 2:VIRG VS NGPU    | 1  | 976.88 | 29.58   | 0.0016 |
| 3:CA1 VS CA2      | 1  | 6.86   | 0.21    | 0.6643 |
| 4:CA1PO VS CA1P1  | 1  | 277.56 | 8.40    | 0.0274 |
| 5:CA2PO VS CA2P1  | 1  | 54.98  | 1.66    | 0.2444 |

Table A3.2-continued.Virgin Soils

DEPENDENT VARIABLE: C-30

| CONTRAST         | DF | SS     | F VALUE | PR > F |
|------------------|----|--------|---------|--------|
| 1:LA VS LE       | 1  | 21.95  | 0.56    | 0.4976 |
| 2:DT VS TR       | 1  | 113.74 | 2.88    | 0.1651 |
| 3:LA&LE VS DT&TR | 1  | 142.97 | 3.62    | 0.1300 |

DEPENDENT VARIABLE: C-100

| CONTRAST         | DF | SS     | F VALUE | PR > F |
|------------------|----|--------|---------|--------|
| 1:LA VS LE       | 1  | 45.02  | 1.08    | 0.3578 |
| 2:DT VS TR       | 1  | 39.19  | 0.94    | 0.3876 |
| 3:LA&LE VS DT&TR | 1  | 206.05 | 4.93    | 0.0905 |

---

Table A3.3 - Correlations for CO<sub>2</sub> evolution.LA-Acrustox SoilGrass

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/N = 8 |          |         |          |          |       |
|------------------------------------------------------------|----------|---------|----------|----------|-------|
|                                                            | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC |
| C-30                                                       | -0.352   | 0.206   | -0.662   | -0.280   | 0.653 |
|                                                            | 0.39     | 0.62    | 0.07     | 0.50     | 0.08  |
| C-100                                                      | -0.332   | 0.270   | -0.652   | -0.269   | 0.637 |
| 0.42                                                       | 0.52     | 0.06    | 0.52     | 0.09     |       |

Legume

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/N = 8 |          |         |          |          |       |
|------------------------------------------------------------|----------|---------|----------|----------|-------|
|                                                            | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC |
| C-30                                                       | -0.352   | 0.206   | -0.347   | -0.556   | 0.654 |
|                                                            | 0.39     | 0.62    | 0.40     | 0.15     | 0.08  |
| C-100                                                      | -0.332   | 0.271   | -0.358   | -0.533   | 0.643 |
|                                                            | 0.42     | 0.52    | 0.38     | 0.17     | 0.09  |

LE-Haplustox SoilGrass

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/N = 12 |          |         |          |          |        |
|-------------------------------------------------------------|----------|---------|----------|----------|--------|
|                                                             | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC  |
| C-30                                                        | 0.602    | -0.461  | -0.484   | 0.758    | -0.161 |
|                                                             | 0.04     | 0.13    | 0.11     | 0.01     | 0.62   |
| C-100                                                       | 0.580    | -0.552  | -0.463   | 0.754    | -0.183 |
|                                                             | 0.05     | 0.06    | 0.13     | 0.004    | 0.57   |

Legume

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/# obs |          |         |          |          |        |
|------------------------------------------------------------|----------|---------|----------|----------|--------|
|                                                            | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC  |
| C-30                                                       | -0.660   | 0.147   | 0.007    | 0.058    | -0.144 |
|                                                            | 0.02     | 0.65    | 0.98     | 0.87     | 0.69   |
|                                                            | 12       | 12      | 12       | 10       | 10     |
| C-100                                                      | -0.666   | 0.079   | -0.056   | 0.053    | -0.069 |
|                                                            | 0.02     | 0.81    | 0.86     | 0.88     | 0.85   |
|                                                            | 12       | 12      | 12       | 10       | 10     |

Table A3.3-continued.Virgin SoilsGrass

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/N = 8 |          |         |          |          |        |
|------------------------------------------------------------|----------|---------|----------|----------|--------|
|                                                            | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC  |
| C-30                                                       | -0.684   | -0.136  | 0.262    | 0.691    | -0.425 |
|                                                            | 0.06     | 0.75    | 0.53     | 0.06     | 0.29   |
| C-100                                                      | -0.757   | -0.369  | 0.245    | 0.780    | -0.434 |
|                                                            | 0.03     | 0.37    | 0.56     | 0.02     | 0.28   |

Legume

| CORRELATION COEFFICIENTS / PROB > :R: UNDER HO:RHO=O/# obs |          |         |          |          |       |
|------------------------------------------------------------|----------|---------|----------|----------|-------|
|                                                            | TKN-INIT | CN-INIT | REC-SOIL | REC-PLNT | UNACC |
| C-30                                                       | -0.536   | 0.849   | -0.562   | 0.143    | 0.426 |
|                                                            | 0.17     | 0.01    | 0.15     | 0.79     | 0.40  |
|                                                            | 8        | 8       | 8        | 6        | 6     |
| C-100                                                      | -0.627   | 0.797   | -0.521   | -0.292   | 0.696 |
|                                                            | 0.10     | 0.02    | 0.19     | 0.57     | 0.12  |
|                                                            | 8        | 8       | 8        | 6        | 6     |

Table A3.4 - Non-linear regression parameter estimates  
using negative exponential format:  
 $Y = B0 * (1 - \exp(-B1 * X))$ .

| Soil | Management | Rep | B0                |                   | B1                |                   |
|------|------------|-----|-------------------|-------------------|-------------------|-------------------|
|      |            |     | Est. <sup>+</sup> | S.E. <sup>‡</sup> | Est. <sup>+</sup> | S.E. <sup>‡</sup> |
| LA   | AD1        | 1   | 48.8507           | 1.1878            | 0.0543            | 0.0032            |
|      |            | 2   | 39.5586           | 1.1206            | 0.0548            | 0.0038            |
|      | AD2        | 1   | 57.5045           | 1.6849            | 0.0519            | 0.0036            |
|      |            | 2   | 47.6313           | 2.1782            | 0.0493            | 0.0052            |
|      | AD3        | 1   | 58.8700           | 1.5803            | 0.0505            | 0.0032            |
|      |            | 2   | 45.6024           | 1.7772            | 0.0473            | 0.0042            |
|      | Virgin     | 1   | 71.6714           | 2.3805            | 0.0480            | 0.0036            |
|      |            | 2   | 57.2543           | 2.1587            | 0.0454            | 0.0038            |
| LE   | Ca1POA     | 1   | 38.7406           | 0.9343            | 0.0704            | 0.0046            |
|      |            | 2   | 37.8883           | 2.0151            | 0.0422            | 0.0048            |
|      | Ca1P1A     | 1   | 57.8965           | 2.1044            | 0.0430            | 0.0034            |
|      |            | 2   | 53.6313           | 3.0004            | 0.0366            | 0.0041            |
|      | Ca2POA     | 1   | 47.8070           | 1.5555            | 0.0463            | 0.0034            |
|      |            | 2   | 42.3672           | 2.7045            | 0.0407            | 0.0055            |
|      | Ca2P1A     | 1   | 57.5536           | 2.1693            | 0.0507            | 0.0045            |
|      |            | 2   | 46.9254           | 2.2817            | 0.0505            | 0.0057            |
|      | Virgin     | 1   | 75.5837           | 2.0595            | 0.0549            | 0.0036            |
|      |            | 2   | 66.7379           | 3.5195            | 0.0434            | 0.0050            |
|      | N3PU       | 1   | 45.5998           | 1.4205            | 0.0473            | 0.0033            |
|      |            | 2   | 34.2224           | 2.1480            | 0.0377            | 0.0048            |

<sup>+</sup> Est. = estimate

<sup>‡</sup> S.E. = standard error, asymptotic

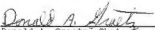
## BIOGRAPHICAL SKETCH

I was born in January 6, 1949, in Porto Alegre, Rio Grande do Sul State, Brazil. I married Elaine Guilherme in June 16, 1973, and our son, Amílcar, was born on May 17, 1980.

I graduated with a degree in Agronomy from the Federal University of Rio Grande do Sul State in December, 1971. I received the Master of Science in Agronomy with a major in soils from the same university in February, 1975.

Since March of 1975, I have been employed with the Empresa Goiana de Pesquisa Agropecuária (EMGOPA), the Goiás State agency for agricultural research, in the core of the cerrado region. Before initiating my Ph.D. program in the University of Florida in January of 1981, I had been conducting research in the area of soil management.

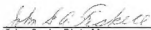
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
Donald A. Graetz, Chairman  
Associate Professor of Soil  
Science

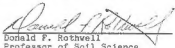
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Edwin C. French, III  
Assistant Professor of Agronomy

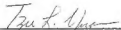
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John G. A. Fiskell  
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
Donald F. Rothwell  
Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
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Tzu L. Yuan  
Professor of Soil Science

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May, 1985

  
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Research